THE PRACTICAL MAGAZINE WITH THE PROFESSIONAL APPROACH

# Elektor Electronics

May 1988

**Signal processing and electronic encryption**

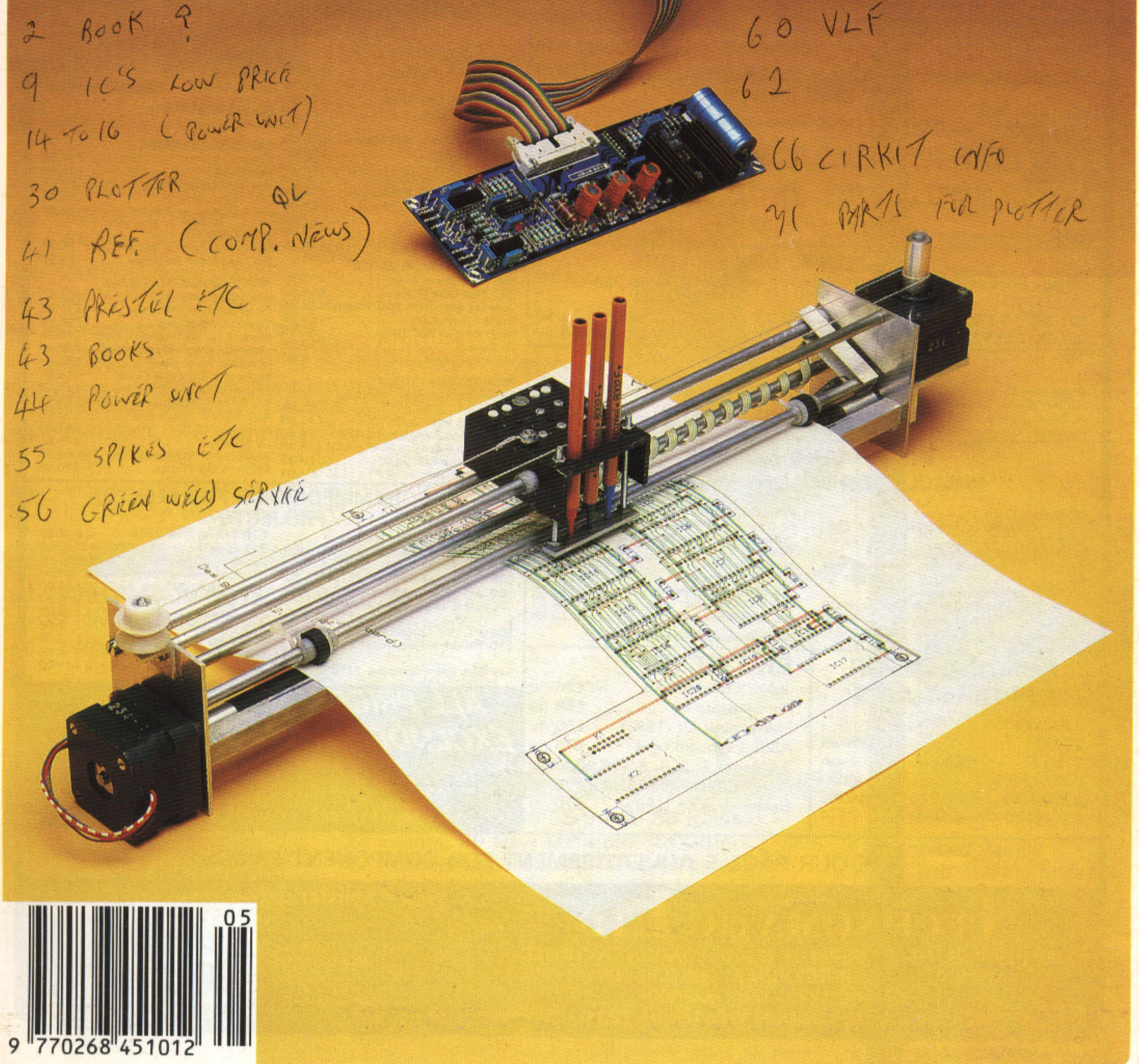
**Microcontroller-driven PSU**

**VLF convertor**

**Plotter**

UK £1·50
IR £2·20
(incl. VAT)

## ARTIFICIAL INTELLIGENCE



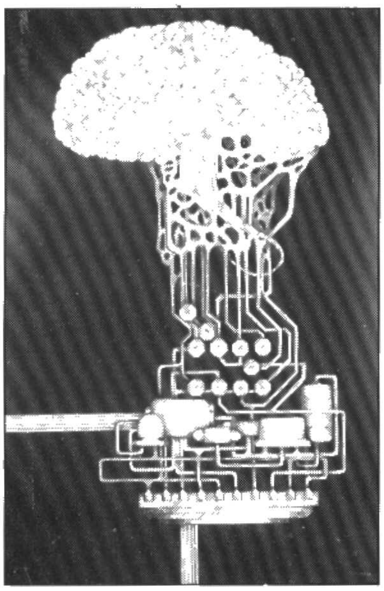
2 BOOK ?
9 IC'S LOW PRICE
14 TO 16 (POWER UNIT)
30 PLOTTER QL
41 REF. (COMP. NEWS)
43 PRESTEL ETC
43 BOOKS
44 POWER UNIT
55 SPIKES ETC
56 GREEN WELL SERVICE
60 VLF
62
66 CIRKIT INFO
71 PARTS FOR PLOTTER

05
9 770268 451012

Elektor Electronics

# CONTENTS

May 1988
Volume 14
Number 156



Artificial intelligence
p. 38


**Editorial**

13 Small companies, SMD, and ASICs

**Audio & Hi-fi**

14 **PROJECT:** Balanced line driver and receiver

17 **PROJECT:** Digital optical transmitter

**Components**

21 Copper-on-ceramic microelectronic technology
by Harry Cole

22 Breakthrough in superconducting materials
by Peter Hartley

**Test & Measurement**

25 Digital storage oscilloscope: a review of the Hameg HM205-2 by Julian Nolan

**Computers**

30 **PROJECT:** Plotter — part 1
Mechanical design by J. Arkema

38 Artificial intelligence
by Mark Seymour

40 Simulating sight in robots
by Arthur Fryatt

**General Interest**

44 **PROJECT:** Microcontroller-driven power supply — part 1

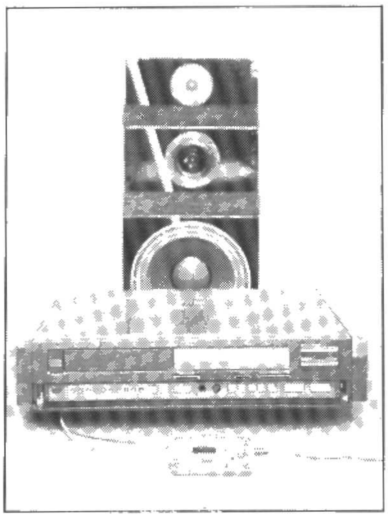
53 Making the weather work for you
by Dr John Houghton and David Houghton

**Radio & Television**

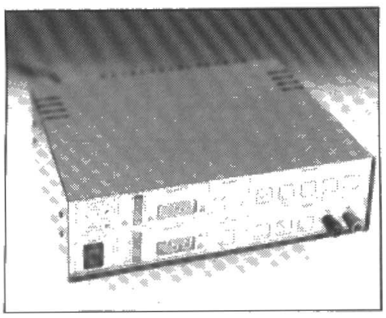
57 **APPLICATION NOTES:** Single-chip multi-standard colour decoder

60 **PROJECT:** VLF convertor

62 Signal processing and electronic encryption
by Brain P. McArdle

Digital optical transmitter
p. 17



Microcontroller-driven PSU
p. 44


**Information**

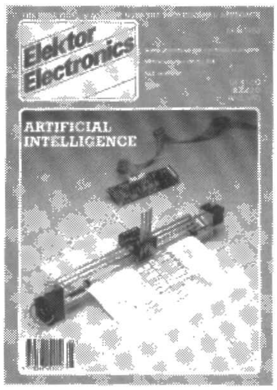
**20-28-41-42-52-55-56-64-65-66** News; **28** Events; **29** New literature; **43** Letters; **67** Readers services; **68** Terms of business

**Guide lines**

**68** Switchboard; **9** Buyers guide; **74** Classified advertisements; **74** Index of advertisers


## In next month's issue:

- NiCd charger
- 64 K RAM for MSX
- Paintbox
- Digital audio interface
- Electrostatic paper holder
- Universal I/O bus for IBM
- HF neon tube lighting
- Holography and lasers produces very precise measurements




***Front cover***
The fairly-simple-to-build plotter described in our May and June issues is available in kit form (see advertisement on p.71) and offers an excellent price/performance ratio.

Elektor Electronics
A Wolters Kluwer Company
**Managing Editor:** Len Seymour
**Personal Assistant:** L. Vousden
**Technical Editor:** J Buiting
**Advertisement executive:**
Pauline O'Rourke
**Editorial offices:**
1 Harlequin Avenue
BRENTFORD TW8 9EW
England
Telephone: 01-847 2618 *(National)*
or +44 1847 2618 *(International)*
**Advertising:** 01-847 2619
**Telex:** 917490 (elektr g)
**Fax:** 01-847 2610
**European offices:**
Postbus 75
6190 AB BEEK (L)
The Netherlands
Telephone: +31 4490 89444
Telex: 56617 (elekt nl)
Fax: +31 4490 70161
**Overseas editions:**
Publitron Publicacoes Tecnicas Ltda
Av Ipiranga 1100, 9° andar
CEP 01040 Sao Paulo — Brazil
**Editor:** Juliano Barsali
Elektor sarl
Route Nationale; Le Seau; B.P. 53
59270 Bailleul — France
**Editors:** D R S Meyer;
G C P Raedersdorf
Elektor Verlag GmbH
Süsterfeld-Straße 25
5100 Aachen — West Germany
**Editor:** E J A Krempelsauer
Elektor EPE
Karaiskaki 14
16673 Voula — Athens — Greece
**Editor:** E Xanthoulis
Elektor Electronics PVT Ltd.
Chhotani Building
52 C, Proctor Road, Grant Road (E)
Bombay 400 007 — India
**Editor:** Surendra Iyer
Elektuur B.V.
Peter Treckpoelstraat 2-4
6191 VK Beek — the Netherlands
**Editor:** P E L Kersemakers
Ferreira & Bento Lda.
R.D. Estefânia, 32-1°
1000 Lisboa — Portugal
**Editor:** Jorge Gonçalves
Ingelek S.A.
Plaza República Ecuador
2-28016 Madrid — Spain
**Editor:** A M Ferrer
Electronic Press AB
Box 63
182 11 Danderyd — Sweden
**Editor:** Bill Cedrum
**International co-ordinating & technical manager:**
K S M Walraven
**International editorial secretariat:**
G W P v Linden; M Pardo
Distribution:
SEYMOUR
334 Brixton Road
LONDON SW9 7AG.
Typeset & composed in the Netherlands by GBS, Beek (L).
Printed in the Netherlands by NDB, Zoeterwoude.


# SMALL COMPANIES, SMD, AND ASICS

After a difficult infancy that started some years ago, surface mount technology appears to be entering an adolescence that promises to be far less turbulent. Most of the world's electronics industry has begun to adopt SMD, and early investors can at last look forward to the rewards of their far-sightedness.

When this magazine first drew attention to the benefits of SMD in 1985, it was, perhaps, not fully realized that a host of technical problems were still waiting to be resolved. These primarily concerned the long-term reliability of the new surface mount units. Also, ensuring that they were fixed, and remained fixed, firmly in position during the normal operational life of the equipment has proved a difficult task.

Another problem has been, and, to some extent, still is, the lack of recognition by equipment designers of the limitations of the new technology. Indeed, many designers did not appreciate that SMD presented a wholly new approach to assembling circuit boards together in operational equipment. This has cost a number of manufacturing concerns dearly, not only in terms of money, but also of time.

Early research indicates that companies that have benefited most are those that have realized at an early stage that in surface mount technology the design of both devices and boards needs to be reevaluated. More particularly, the successful companies appear to be those that have combined semi-custom design with surface mount technology.

Already, it is becoming clear that this realization has been a shot in the arm for ASIC (Application Specific Integrated Circuit) manufacturers. This, coupled with other developments in the semiconductor industry, have steered equipment makers as well as users towards the use of ASICs. This is good for Britain, which has a strong base of ASIC production in companies like Plessey and Ferranti. The UK ASIC industry has already built a substantial export market, but, as always, our European, American and Japanese competitors are not sitting still.

A recent government report points to an odd and disquieting development: small companies, in the UK as well as abroad, are on the whole still reluctant to adopt the new technologies, although they have most to gain from doing so. Surface mount technology, combined with ASICs, will enable even small companies to compete in hi-tech developments.

It would not be healthy for the country if only a handful of large companies would come to control the use of these new technologies, or the design and manufacture of ASICs. Interestingly, most of the semiconductor manufacturers are said to be eager to widen their base of small customers. It would seem, therefore, that it is up to the smaller companies to shed their reluctance to approach the big suppliers direct or through the existing distribution channels and take advantage of the available design services. The alternative is almost certainly overwhelming competition from the bigger manufacturers whose designers and production managers show no reservations about the use of ASIC design services.

# BALANCED LINE DRIVER AND RECEIVER

**These high-quality audio circuits are intended to overcome all the problems caused by noise picked up by long unbalanced signal lines between signal sources and amplifiers. Applications can be found in public address systems, studios, active loudspeakers, mixer desks and intercoms.**

The principle of balanced transmission of audio signals is relatively simple as shown in Fig. 1. The unbalanced signal from, for example, a preamplifier is applied to an unbalanced-to-balanced converter, which drives two output lines. One of these carries the inverted, the other the non-inverted signal. Noise picked up by the cable between the line driver and the receiver is superimposed on both AF signals. The complementary phase AF signals are added in the line receiver to give an unbalanced output signal, which is a copy of the signal fed to the line driver. In this process, noise is effectively eliminated because its phase is identical on both input lines of the receiver.

In studios, practically all lines for interconnecting equipment are of the balanced type. Balanced-to-unbalanced conversion and vice versa is usually effected with the aid of high-quality transformers. Unfortunately, these are hard to obtain and relatively expensive devices, and for this reason an alternative based on semiconductors is offered here.

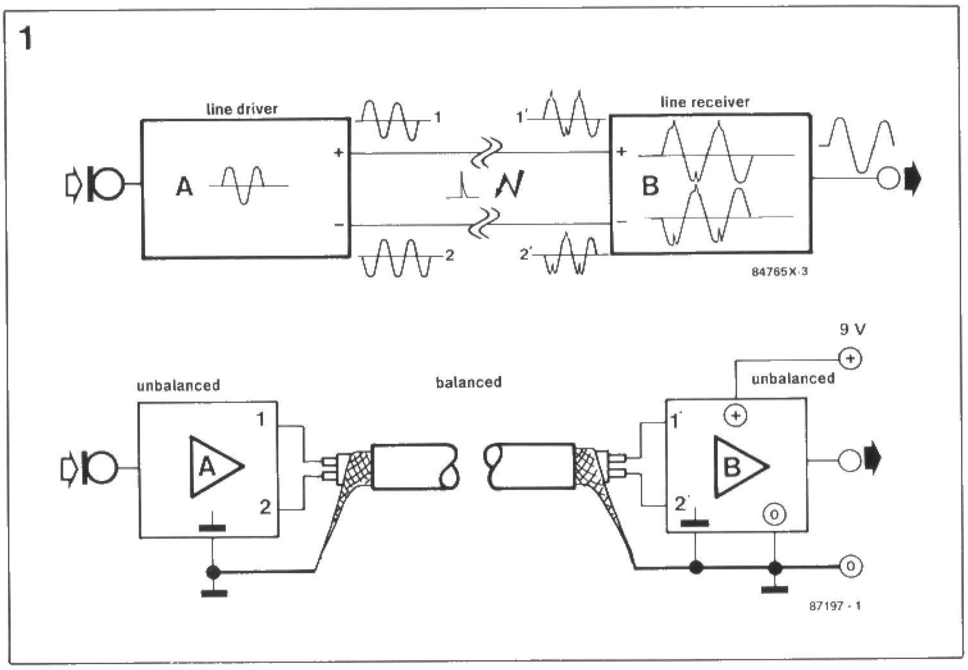



**Fig. 1. Noise on long cables between audio equipment can be eliminated by the use of a balanced line driver and receiver.**

## Line driver

The circuit diagram of the line driver is given in Fig. 2. The unbalanced input signal is applied to buffer $A_1$. This drives a non-inverting amplifier, $A_2$, and an inverting amplifier, $A_3$. Both opamps are configured for an amplification of about 2. The amplification is $1+R_1/R_2$ in the case of $A_2$, and $-[(R_4+R_5)/R_3]$ in the case of $A_3$ (notice that the minus sign denotes inversion of the input signal, not attenuation). Resistors $R_6$ and $R_7$ correct error voltages caused by the quiescent input currents of inverting opamps $A_1$ and $A_3$. Capacitors $C_7$, $C_8$ and $C_9$ ensure very low distortion and stable gain up to the $-3$ dB roll-off frequency of 350 kHz. The opamps of the type stated in the circuit diagram give an output noise level of about 20 $\mu V_{rms}$. This performance can be equalled by more commonly found opamps such as the Type NE5534 (instead of the OP-27) and the Type NE5532 (instead of the OP-227), but only if all resistors in the circuit are ultra-low noise types with a tolerance of 0.1% or better to guarantee equal amplitudes of the balanced output signals.

## Line receiver: introducing the AMP-01

Special attention should be paid in the receiver design to low overall distortion. There are, however, awkward constraints to take into consideration. The most important of these are the common-mode rejection of the opamp used, and cable capacitance. It is, therefore, necessary to use an amplifier that is geared to compensation, not amplification, of these sources of distortion.

The Type AMP-01 precision instrumentation amplifier from PMI should meet with this requirement. The AMP-01 houses 4 interconnected opamps that amplify the potential difference between the input pins by a factor that can be accurately defined. The internal structure of the AMP-01 is shown in Fig. 3. Since the device is essentially an instrumentation amplifier, it rejects signals common to both inputs. Unlike the complementary AF signals, noise induced on the balanced line between driver and receiver is of the same phase and amplitude at both inputs of the line receiver. Hence, it is common to both amplifier inputs, so that it is effectively suppressed at the output.

In contrast to an operational amplifier, an instrumentation amplifier requires precise internal feedback. In the AMP-01, current feedback is used. This approach has significant advantages over resistive feedback:

- High common-mode rejection (CMR): approx. 130 dB at a gain of 1,000.

- Closed loop amplification, $A_{VCL}$, can be set by the ratio of only two external resistors: $A_{VCL}=20R_{15}/R_{16}$. This allows any practical gain to be set with high precision and low gain—temperature coefficient.
- The current feedback design is immune to CMR degradation when series resistance is added to the reference input. A small (trimmable) offset change results from added resistance, e.g., a printed circuit track.

Close tolerance low-drift thin-film resistors are integrated on the AMP-01 substate to minimize output offset drift with temperature.

Input transistors $Q_1$ and $Q_2$ feed active loads, so that the amplification of this stage is about 4,000. Output amplifier $A_1$ is a 2-stage circuit offering an amplification of 50,000 in a 100 Ω load. The open-loop gain of the AMP-01 is about $2\times10^8$. Stability and linearity of the device are excellent, also at relatively high closed-loop gains.

Ion-implanted super-beta transistors are used in combination with a patented bias-current cancellation circuit. Input quiescent current remains below 15 nA over the temperature range −25°C to +85°C. A new geometry is used for the input transistors, resulting in an input noise of only 5 nV/$\sqrt{\text{Hz}}$ at a gain of 1,000. This noise includes contributions from the gain-determining and overload protection resistors. The input stage achieves an offset voltage drift of less than 0.3 µV/°C.

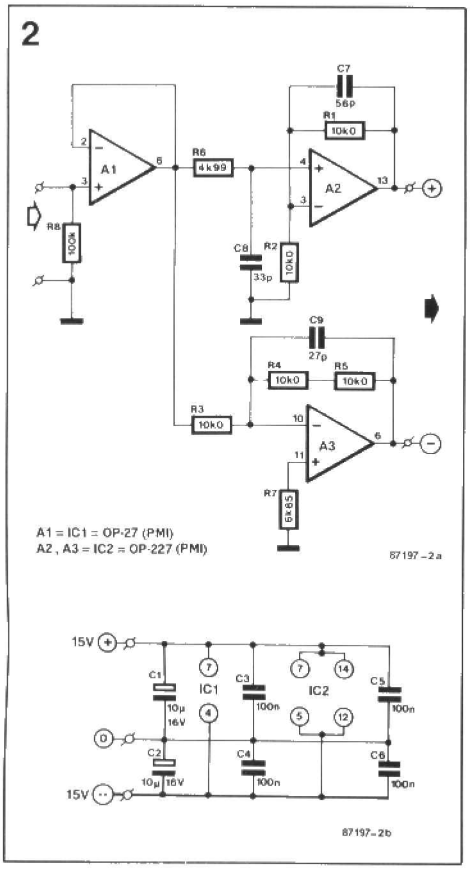



Fig. 2. Circuit diagram of the balanced line driver.

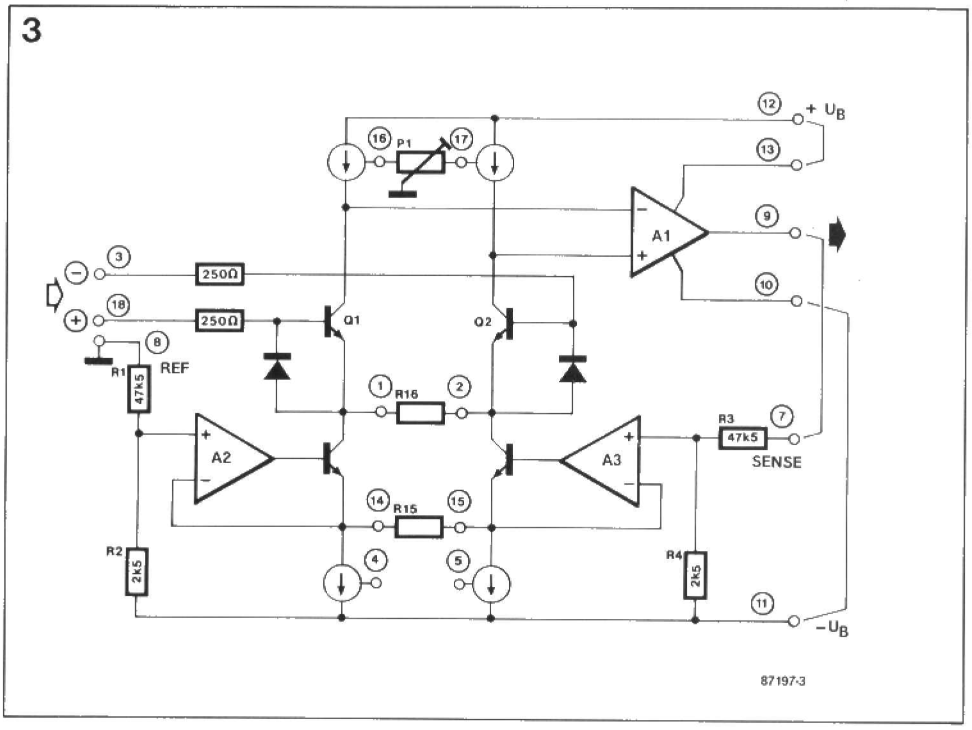



Fig. 3. Internal structure of the Type AMP-01 precision instrumentation amplifier from PMI.

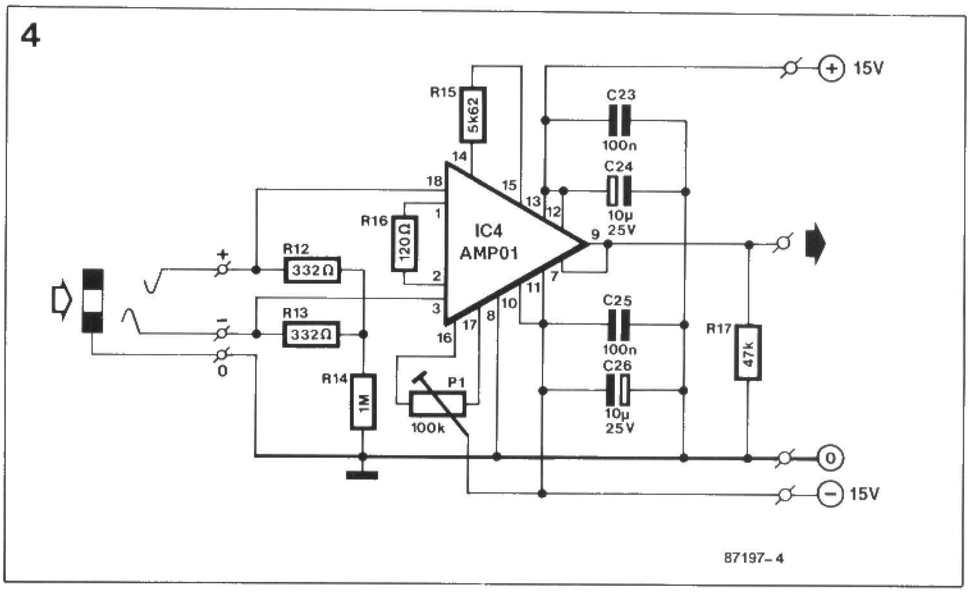



Fig. 4. Circuit diagram of the balanced line receiver.

The AMP-01 uses a special circuit for compensation of the load capacitance, ruling out any likelihood of instability over a wide range of practical gain. The high output current capability of 90 $mA_p$ allows the slew-rate of 4.5 µs to be maintained with load capacitance as high as 15 nF.

The circuit diagram of the balanced line receiver is shown in Fig. 4. Resistors $R_{15}$ and $R_{16}$ are dimensioned for an amplification of about 940. The value of $R_{15}$ may be increased to reduce amplification as required for a particular application. The input offset voltage is set to nought with the aid of $P_1$. The symmetrical supply rails to the AMP-01 are decoupled with parallel combinations of a solid and an electrolytic capacitor. The potentials at the differential inputs of the chip are fixed with $R_{12}$-$R_{13}$-$R_{14}$.

The balanced line receiver has a 3 dB bandwidth of about 30 kHz. Noise level at the output was measured at 5.3 $mV_{rms}$ with inputs not connected, and 3.5 $mV_{rms}$ with inputs briefly connected to ground.

## Power supply

The power supply shown in Fig. 5 should be familiar to constructors of previous high quality audio projects carried in this magazine. A number of readers have queried the use of the Type LM325 in this supply, and a short description of this device is, therefore, given below.

The LM325 can supply equal symmetrical output voltages whose absolute value is accurate within 1%. Without external series regulator transistors, the device

achieves a load regulation of 0.06% at a maximum output current of 100 mA. On board the IC are a current limiter and an overheating protection circuit. The onset point of the current limiter is defined by an external resistor. Quiescent current consumption of the LM325 is only 3 mA, while maximum input voltage is ±30 V. This makes it possible, in many cases, to feed the regulator direct from the existing symmetrical supply in the power amplifier. Bridge rectifier $D_1 \ldots D_4$ incl. ($B_1$) and rattle suppression capacitors $C_{10} \ldots C_{13}$ incl. may then be omitted, but due attention should be paid to the working voltage of $C_{14}$ and $C_{16}$.

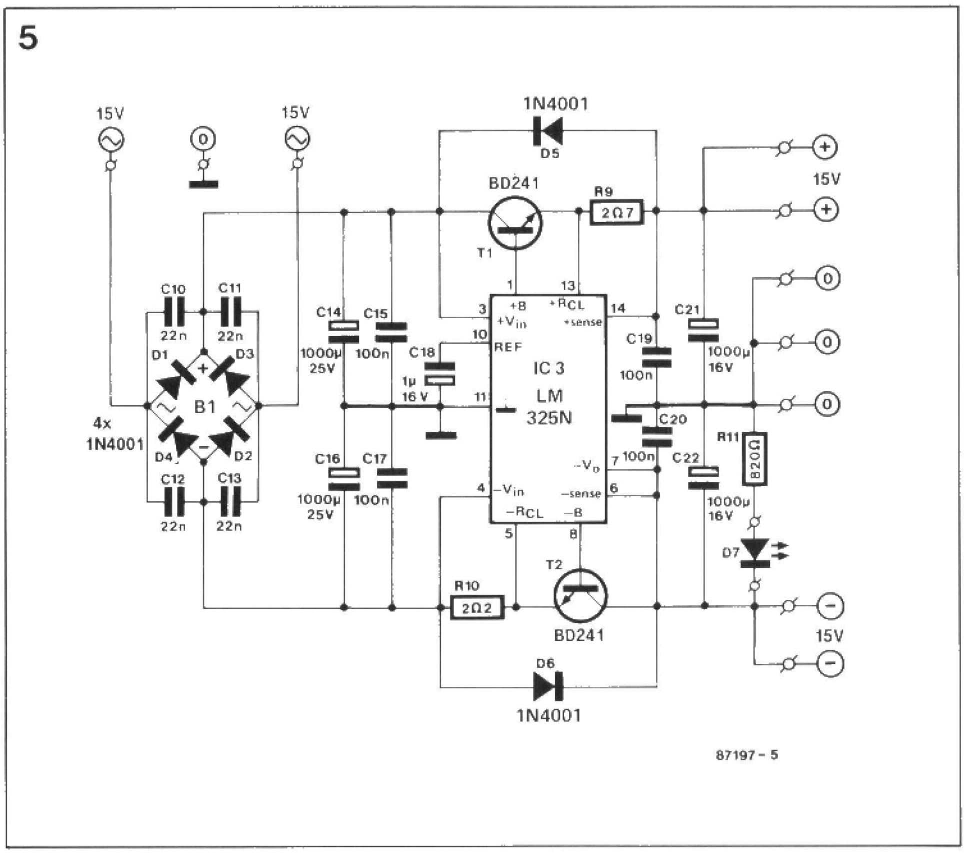



**Fig. 5. The symmetrical power supply is a design based on precision voltage regulator Type LM325.**

## Construction

The three circuits discussed are accomodated on a single printed circuit board, whose track layout and component overlay are shown in Fig. 6. Depending on the application of the balanced line driver and receiver, the PCB may be cut in two or three to enable fitting the circuits in the relevant locations.

The screened, balanced, cable between the line driver and receiver is connected as shown in the lower drawing of Fig. 1. It is recommended to use high-quality cable and XLR (Canon/Neutrik) connectors.

*Gb*

The functional description of the Type AMP-01 is based on information provided in *Linear and Conversion Products. 1986/1987 Data Book*. Precision Monolithics Incorporated.

**Parts list**

Resistors:

R1 . . . R5 incl. = 10KF
R6 = 4K99F
R7 = 6K55F
R8 = 100KF
R9 = 2R7J
R10 = 2R2J
R11 = 820RJ
R12;R13 = 332RF
R14 = 1M0F
R15 = 5K62F
R16 = 120RF
R17 = 47KJ
P1 = 100KK preset H

Note: resistor values are coded to BS1852: suffix F = 1%; J = 5%; K = 10%.
A range of high stability, low-noise resistors is available from AudioKits Precision Components.

Capacitors:

C1;C2;C24;C26 = 10µ; 25 V; radial
C3 . . . C6 incl.;C15;C17;C19;C20;C23;C25 = 100n
C7 = 56p
C8 = 33p
C9 = 27p
C10 . . . C13 incl. = 22n
C14;C16 = 1000µ; 25 V; radial
C18 = 1µ0; 16 V; radial.
C21;C22 = 1000µ; 16 V; radial

Semiconductors:

D1 . . . D6 incl. = 1N4001
D7 = LED
T1;T2 = BD241
IC1 = OP-27*
IC2 = OP-227*
IC3 = LM325N
IC4 = AMP-01*

* Precision Monolithics Incorporated. UK distributors are listed on InfoCard 508 (*EE* May 1987).

Miscellaneous:

PCB Type 87197 (see Readers Services page).

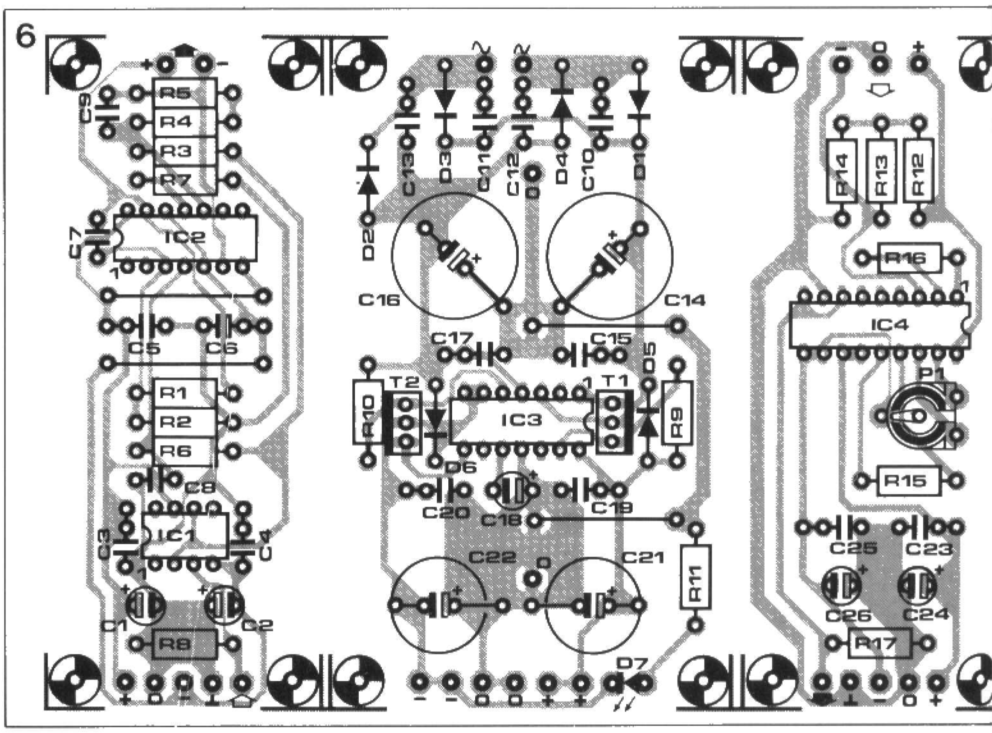



**Fig. 6. Printed circuit board for building the line driver, receiver and power supply.**

# DIGITAL OPTICAL TRANSMITTER

**Virtually all currently available compact disc players are fitted with a digital output, but a digital *optical* output is only available on top-of-the-range models. This design idea describes an optical transmitter that makes it possible to drive an active loudspeaker from a standard CD player via a fibre optic link.**

**Editorial Note**

*This article was not included in last month's issue because availability of the key component in the project could not be ascertained in time.*

*Considering the interest of many of our readers in high-quality audio technology, and having announced the article on an earlier occasion, it was decided to go ahead with publication this month, in spite of the fact that the recently introduced inra-red module in the transmitter is, to our knowledge, only available direct from the West German manufacturer, Delec.*

The cost of fibre optic links for use in in high-end audio equipment is coming down rapidly. Fibre optics can help towards solving some of the problems inherent to traditional cable links by ensuring:

- freedom from induced hum or electro-magnetic interference;
- complete galvanic insulation guarantees safety, and eliminates any risk of earth loops;
- freedom from crosstalk between parallel running cables.
- Polymer fibre optic cables are thin, flexible and unobtrusive.

A combination of a fibre optic transmitter driven by the digital signal from the compact disc player, a length of polymer cable terminated in suitable connectors, and a fibre optic receiver plus digital-to-analogue converter fitted in an active loudspeaker: very nearly what is considered by many high-end audio enthusiasts the ideal AF transmission link. Arguably, this set-up is superior in all respects to any of the hitherto used systems based on analogue modulation of signals conveyed via an audio fibre-optic link. Irrespective of whether a sinewave or a rectangular signal is used as the carrier onto which the digital CD signal is modulated, these systems remain *analogue* in essence, and any reference in sales ploys to "all-digital transmission" is misplaced and technically incorrect. This is not to bring in a qualitative verdict upon such systems, however, since many of the frequency modulators used are of very high quality. It is merely the notion "digital" that is misinterpreted. The frequency modulation used is and remains an additional analogue "long way" that can be eliminated from signals sent to an active loudspeaker.

## Digital optical transmitter

Digital optical transmitters are relatively simple circuits based on highly efficient infra-red emitting diodes. As an example, Fig. 1 shows a transmitter that forms part of Hirschmann's fibre optic kit OXE 101. The TTL input signal (DATA) is applied to either input A or B of a NAND gate. The non-used input is connected to $V_{cc}$ (+5 V). Transistor $T_5$ drives IRED $D_4$. Schottky diode $D_3$ prevents the transistor being driven into saturation, while speed-up capacitor $C_5$ ensures fast switching response. The infra-red emitting diode (IRED) is fitted in a special PCB-mount socket that receives the snap-in plug on the fibre optic cable.

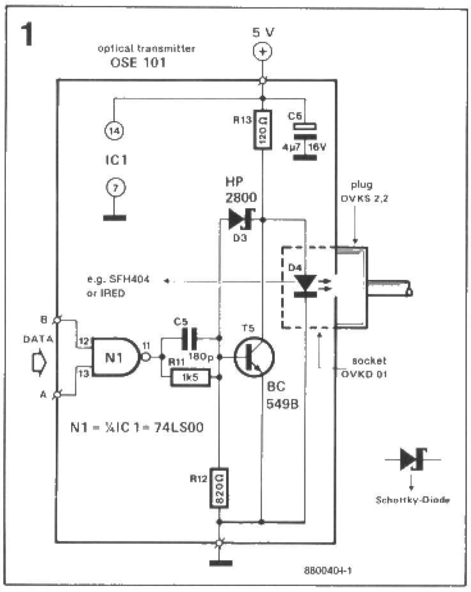



**Fig. 1. Circuit diagram of the Hirschmann optical transmitter included in development kit OXE 101.**

Fitting the plug onto the fibre optic cable is relatively simple, and requires no soldering: cutting and stripping is done with a sharp knife and jaw strippers, and the cable end is carefully smoothed with sandpaper before it is pushed into the connector and secured with a ferrule or locking nut.

The maximum cable length depends on the transmitter power in combination with the attenuation of transmission link, i.e., the cable and connectors. A common value for the cable attenuation is 0.3 to 0.2 dB/m at a cost of about 50 p/m. The maximum usable range of the Hirschmann system is of the order of 40 m. The transmitter power can be defined by series resistor $R_{13}$ in Fig. 1. With $R_{13}$=120 Ω, the forward diode current is 25 mA, resulting in a radiant power of 16 µW coupled into the polymer cable with a core diameter of 1 mm. Increasing the diode current to the maximum permissible value of 50 mA ($R_{13}$=60 Ω) doubles the transmitted power, but not the maximum range, which is only increased by about 10 m. In any case, the range of a conventional fibre optic transmitter such as the Hirschmann device is sufficient for most living rooms. The pulse response of the IREDs used is generally adequate for conveying data at rates up to 10 Mbit/s in non return to zero (NRZ) transmission.

The Hirschmann fibre optic transmitter is composed of discrete parts fitted onto a PCB. Other manufacturers of fibre optic components have already started to integrate emitter and receiver devices. Figure 2 shows the TOSLINK single-chip fibre optic interface plus transmitter from Toshiba. This module can be fitted direct onto a PC board, and requires no

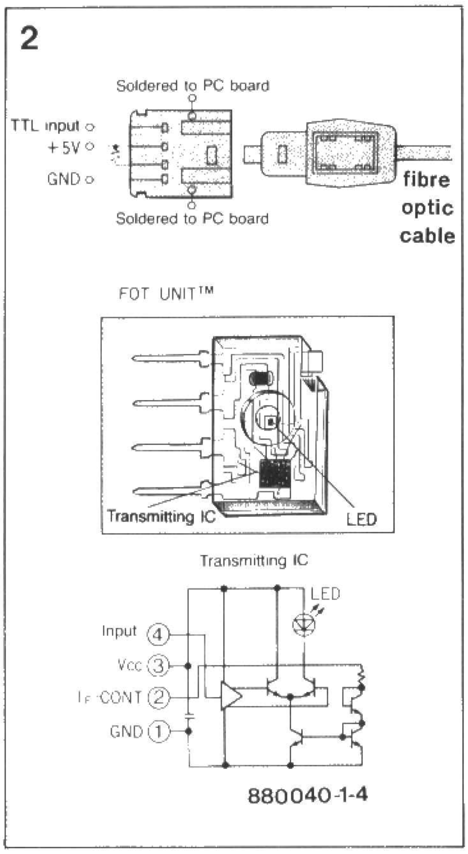



**Fig. 2. The TOSLINK single-chip fibre optic transmitter from Toshiba.**

further parts to receive the plug on the fibre optic cable. The emitter diode is fitted behind a small window in the centre of the IC. An exteral connection, $I_F$, makes it possible to set the forward diode current with the aid of a series resistor to $V_{cc}$ (+5 V).

Neither the Hirschmann nor the Toshiba system discussed above can be driven direct from the digital output on the CD player, since this usually supplies signals to the *Digital Audio Interface* (Philips-Sony) standard, which is, unfortunately, not TTL-compatible.

## Interface considerations

The digital output on most CD players is unbalanced, yet free from a reference voltage level. On an oscilloscope, the output signal does not look digital at all: rather, it is a sinusoidal alternating voltage with an amplitude of 500 $mV_{pp}$. The prescribed termination resistance, 75 Ω, is the same as that used in video systems. Figure 3 shows that the signal is none the less digital, as revealed by the use of a Schmitt-trigger. The logic ones and zeros are somewhat difficult to distinguish owing to the so-called *biphase mark coding* of the digital signal.

Toshiba supply a special TOSLINK module provided with an AC coupled input for the digital audio signal. This module, designated TOML172, appears to have been adopted as the standard fibre optic interface, and is already being used in the Type TOTX172 transmitter fitted in a range of top class CD players. It is, however, less suited to use in an upgrade system, because it has a relatively short transmission range of about 5 m at a diode current of 20 mA, and in addition is fairly difficult to obtain. Obviously, the limited range is a particular disadvantage when an active loudspeaker is to be driven.

A recently introduced fibre optic transmitter module from Delec of Federal Germany has a much larger range thanks to the use of an emitter operated at 40 mA. This module can handle data rates up to 20 Mbit/s, and is simple to use in conjunction with the associated receiver module that will be discussed in a forthcoming design idea.

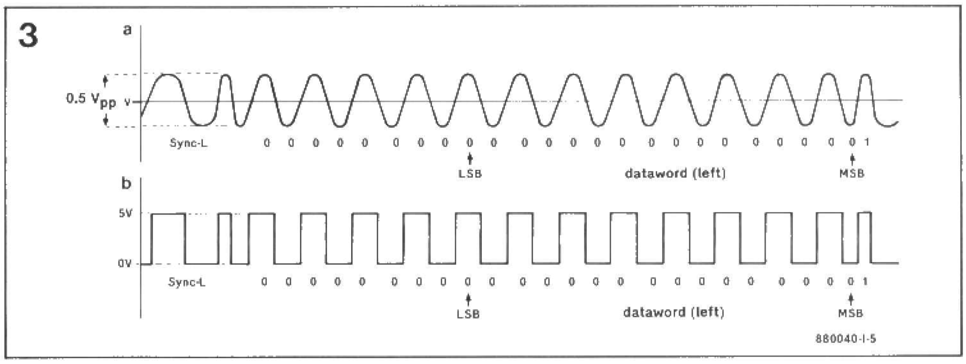



**Fig. 3. Sinusoidal signal (a) supplied by the digital output of a compact disc player converted to logic high and low levels (b) with the aid of a Schmitt-trigger.**

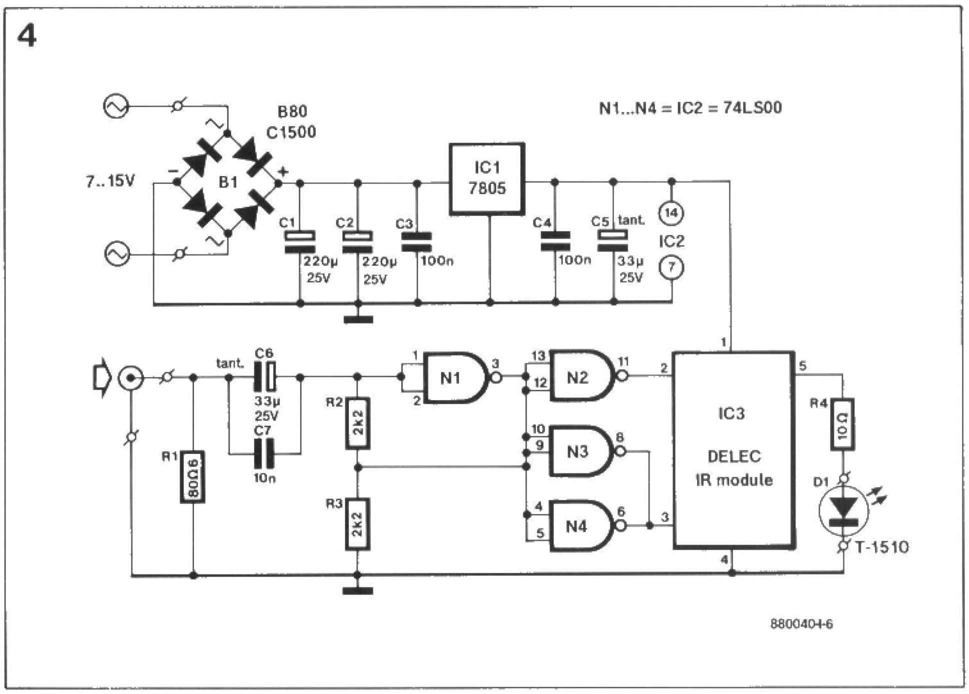



**Fig. 4. Circuit diagram of the digital optical transmitter based on the IR module from Delec.**

## The practical design

The circuit diagram of the digital optical transmitter is shown in Fig. 4. The digital signal from the CD player is applied to the circuit via a short length of thin coaxial cable or shielded wire terminated in a phono socket. The input impedance of the transmitter is close to 75 Ω, which is the total equivalent resistance of $R_1$ and capacitively coupled combination $R_2$-$R_3$-$N_1$-$N_3$-$N_4$. Gate $N_1$ and feedback resistors $R_2$-$R_3$ form an amplifier for converting the input signal from sinusoidal to rectangular. The other gates in the 74LS00 package function as drivers for the transmitter module.

The block diagram of the module (see Fig. 5) shows that the input amplifier has two inputs. A differential network *dU/dT* ensures clearly defined pulse transitions, and feeds the signal to the IRED driver, which is capable of sinking at least 40 mA. The IRED used here is the Type T-1510 from Hewlett Packard,

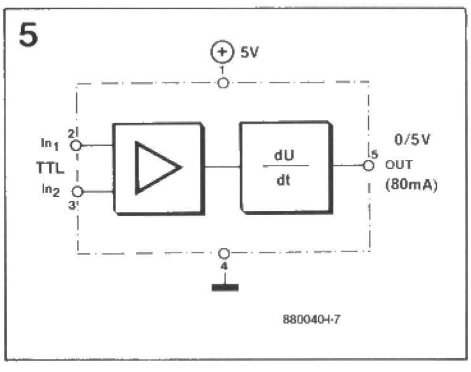



**Fig. 5. Functional representation of the Delec module.**

6

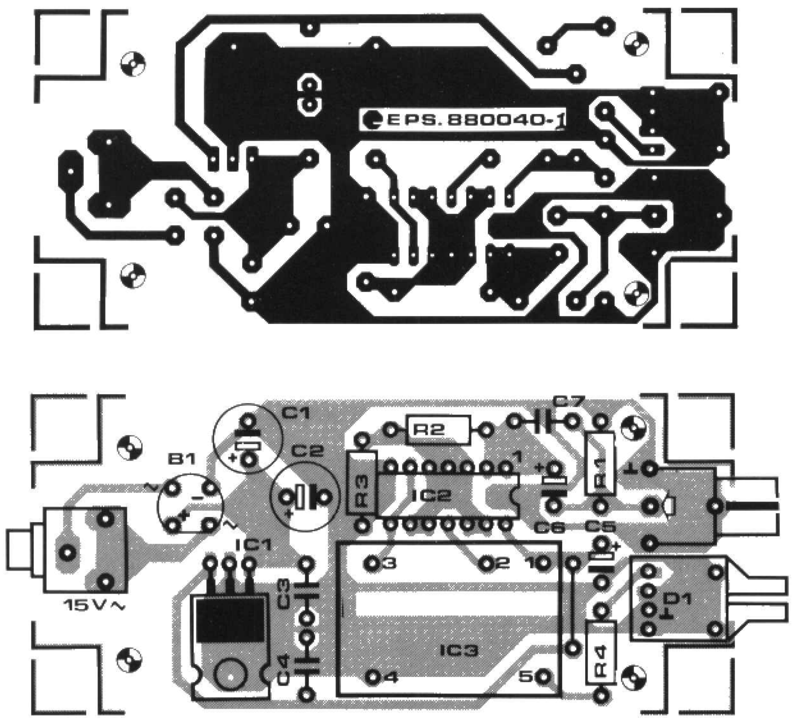



Fig. 6. Printed circuit board for the digital optical transmitter.

**Parts list**

Resistors (±5%):

R1 = 80R6F
R2;R3 = 2K2F
R4 = 10R

Capacitors:

C1;C2 = 220μ; 35 V
C3;C4 = 100n
C5;C6 = 33μ; 25 V; tantalum
C7 = 10n

Semiconductors:

B1 = bridge rectifier B80C1500
D1 = T-1510 (Hewlett-Packard • Components Group • Harman House • 1 George Street • Uxbridge • Middlesex UB8 1YH. Tel.: (0895) 72020. Tlx: 893134/5.
IC1 = 7805
IC2 = 74LS00
IC3 = IR transmitter module. Available from Delec Electronic GmbH • Dieselstrasse 30 • 6352 Obermörlen • West Germany. Telephone: +49 (6002) 1430.

Miscellaneous:

3.5 mm jack socket for PCB mounting.
gold-plated phono socket for PCB mounting.
PCB Type 880040-1 (see Readers Services page).

which features relatively high radiant power and fast pulse response.
The power supply for the fibre optic transmitter is of conventional design, and requires no further discussion. The input voltage is obtained from a suitable mains transformer, or a mains adapter, which should be able to deliver at least 300 mA (AC or DC).

The printed circuit board for the digital optical transmitter is shown in Fig. 6. The digital input socket is preferably a gold-plated phono type for PCB mounting. The completed board may be fitted in an ABS enclosure—screening should not be required here.
The optical emitter is housed in a specially aligned socket assembly which is simple to fit onto the PCB. The mating plug is a small plastic tube that receives the fibre optic cable. Details on

8

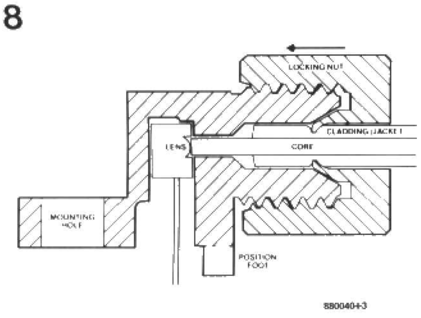
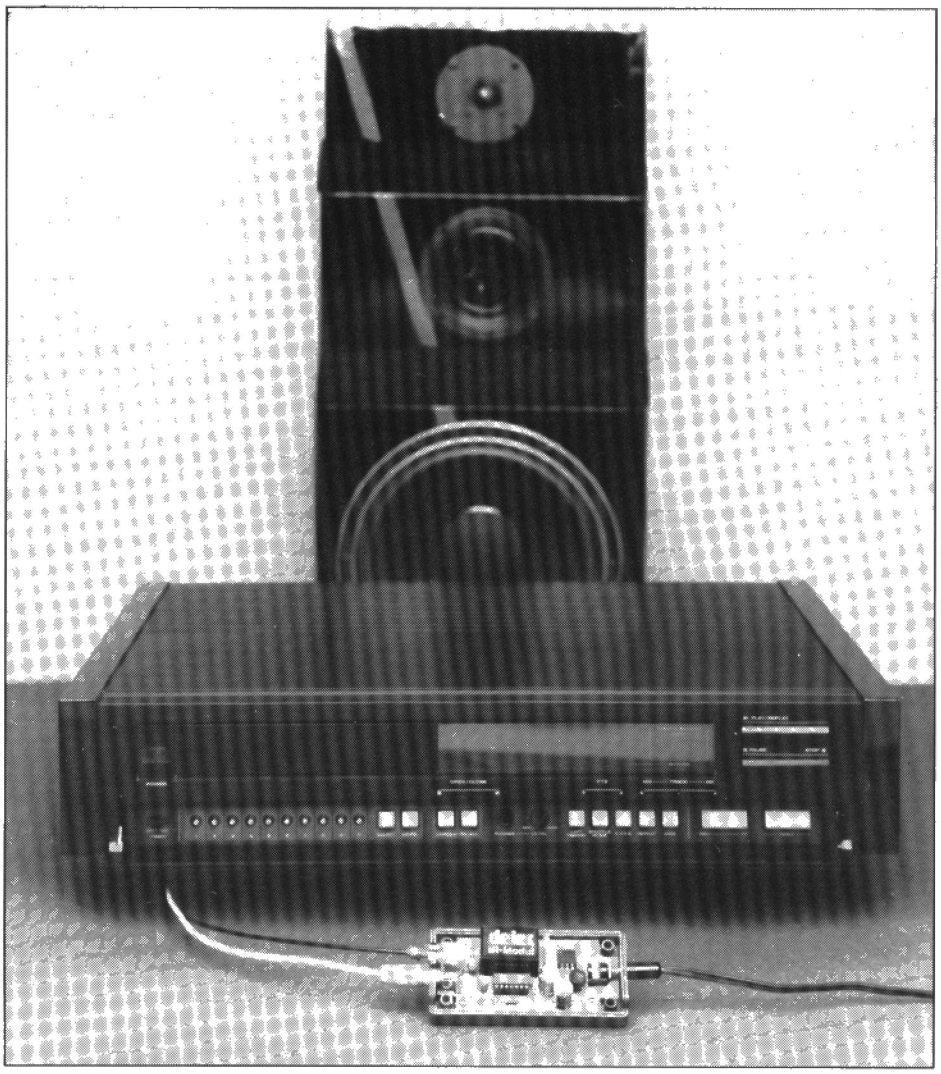



Fig. 8. Cross-sectional view of the Motorola fibre optic connection system.



fibre optic transmit and receive components from Motorola are given in Figs. 7 and 8.

The fibre optic receiver and 16-bit, quadruple oversampling, D-A converter with will be discussed in a forthcoming issue of *Elektor Electronics*. *Gb*

**For further reading:**

- Photonics. *Elektor Electronics* March 1986, p. 46.
- The compact disc. *Elektor Electronics* July/August 1987, p. 39.
- Application note for TOSLINK GH/HH. Toshiba ref. no. 3904C 86-8(H). Toshiba Europe GmbH • Hammer Landstrasse 115 • 4040 Neuss 1 • Federal Germany. Toshiba (UK) Ltd. • Toshiba House • Frimley Road • Camberley • Surrey GU16 15JJ. Telephone: (0276) 62222.

*Note:* We remind readers of the fact that this article is a Design Idea. Accordingly, it deals with recently introduced components, whose general availability can not be guaranteed at the time of publication. The relevant sources are, however, indicated in the parts list. The prototype of the digital optical transmitter shown in the accompanying photograph incorporates a pre-production type of the Delec IR module. Also note that a comprehensive range of fibre optic components is available from Electromail • P.O. Box 33 • Corby • Northants NN17 9EL.

7

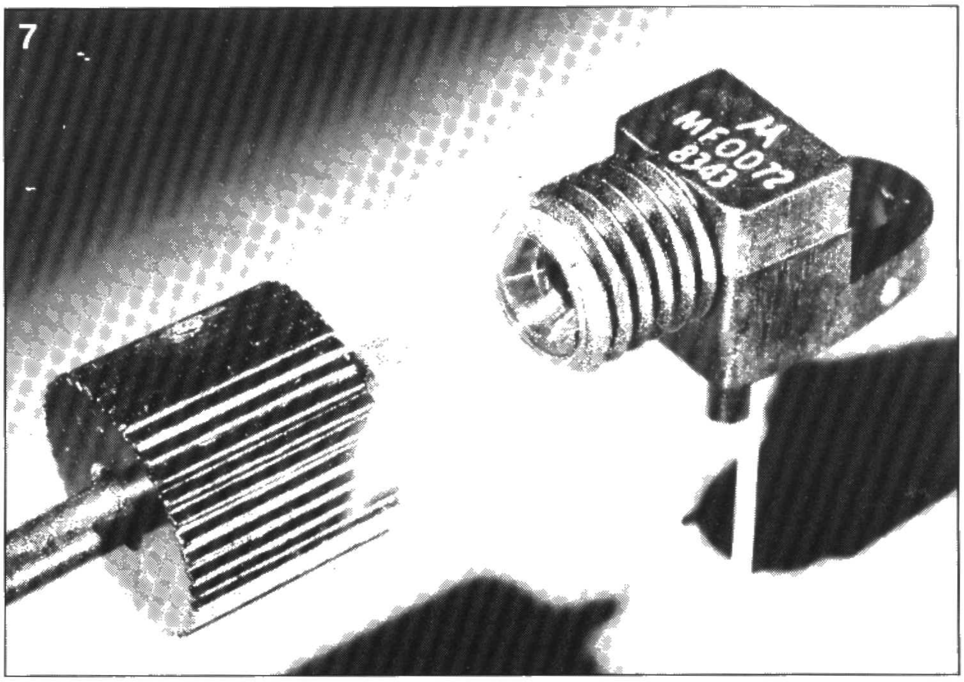



**Fig. 7. Optical connection system from Motorola. The sender diode is housed in the PCB-mount socket.**

9

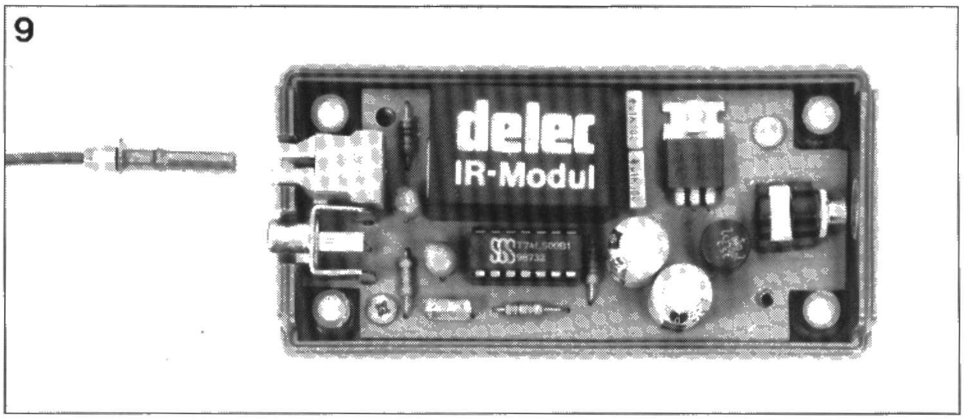
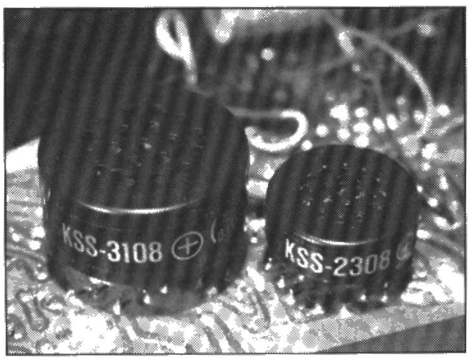



**Fig. 9. Prototype of the digital optical transmitter connected to a fibre optic cable via a Hewlett-Packard plug.**

# AUDIO & HI-FI NEWS

## Enclosed speakers for PCB mounting

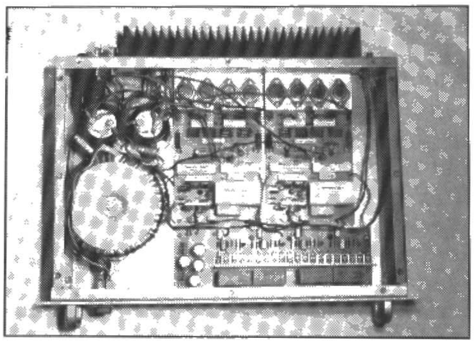
Roxburgh Electronics has introduced two new models to its range of miniature loudspeakers: the KSS2308 and KSS3108. These are fully enclosed in an ABS housing to provide a rugged unit protected from damage to the Mylar cone and fitted with pin terminals suitable for mounting direct onto a PCB.




The KSS2308 is 23 mm in diameter by 8.7 mm high, with 10 mm pin pitch. The KSS3108 is 32 mm in diameter by 15 mm high with 17.5 mm pin pitch. Both speakers have an impedance of 8 ohms. Input ratings are 150 W and 200 W and frequency ranges 700—3000 Hz and 700—4000 Hz respectively.
Further information from: Roxburgh Electronics Ltd • 22 Winchelsea Road • RYE • East Sussex TN31 7EL • Telephone (0797) 223777.

## Power amplifier kits

Audiokits have introduced a new, high-performance power amplifier: the Virtuoso. Designed by Graham Nalty, the amplifier is designed to provide about 100 $W_{rms}$ stereo into an 8-ohm load. Optional additions provide for 150 W and 200 W bridged mono operation.
Standard versions of the Virtuoso use high-quality components, comparable to



some of the better quality proprietary amplifiers. The upgraded versions use the highest quality components currently available.
Prices of the kits range from around £300 for a standard stereo amplifier to about £800 for a 200 W bridged mono amplifier.
Further information from Audiokits Precision Components • 6 Mill Close • Borrowash • Derby DE7 3GU • Telephone (0332) 674929.

# COPPER-ON-CERAMIC MICRO-ELECTRONIC TECHNOLOGY

by Harry Cole, CEng, MIERE

**As the technology of modern micro-electronic circuitry advances, so too does the need to convey digitally coded signals at ever increasing rates. This requirement assumes considerable importance in the multi-layer type of circuit board where many widely spaced ICs have to be interconnected with negligible loss of amplitude.**

Traditionally, gold has been used for interconnection purposes in chip carriers intended for military and aerospace applications where high reliability is of prime importance. Unfortunately, the relatively high electrical resistivity of gold (0.02 $\mu\Omega$ m) and the need for thinner interconnections makes this material unsuitable for the interconnection of densely packed ICs.

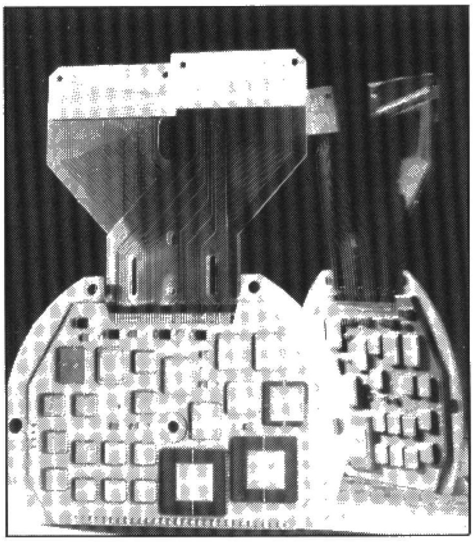
Copper, although lacking some of the desirable properties of gold, has a resistivity of 0.016 $\mu\Omega$ m which is considerably lower and has good solderability. It is much cheaper and has good adhesion properties when bonded to circuit board materials.

The Micro-electronics Technology Centre of British Aerospace's Air Weapons Division at Hatfield has devoted considerable research into the use of copper interconnections laid down on substrates formed of aluminium oxide ceramic. It has developed a fully documented repeatable process that can produce substrates in a variety of flat rectangular sizes up to 152 mm × 183 mm.

## Glass sealing glaze

After being processed, the substrate can be machined by laser beam to virtually any shape, complete with access holes as required. The circuit interconnections are laid down on the ceramic substrate using screen printing technology, and circuit tracks as thin as 0.18 mm can be produced.

Each circuit board may have up to six separate conducting layers, including gridded power and ground (earth) planes, the top layers containing the electrode attachment pads for the components to be fitted. Electrical isolation between the copper conducting layers is achieved by printing from two to five layers of dielectric material, the final thickness being tailored to suit the required insulating properties of the circuit being constructed.



**Double sided copper-on-ceramic electronic module.**

Interconnection between various metal layers is achieved by the printing of copper connector "slugs" in an isolation window cut into the dielectric insulation. This form of connection is known as a "via".

The final printed layer of each board takes the form of a high glass content glaze that effectively seals all preceding conductor layers from environmental hazards during subsequent manufacturing processes. A complete circuit may undergo as many as 50 screen printing operations and 30 separate firing cycles. During each firing cycle the printed substrate is subjected to a temperature profile that peaks at about 900 °C.

## Special furnace

In the atmosphere of a conventional furnace such a temperature would cause the printed copper to oxidize, with consequent degradation of its electrical performance and solderability. For this reason, copper printed substrates are fired in an inert nitrogen atmosphere containing a critically controlled doping level of oxygen. The special furnace was designed in-house by the Micro-electronics Technology Centre at Hatfield.

When manufacture is complete, the printed substrate is subjected to a rigorous programme of bare-board electrical tests to verify the correctness and continuity of its circuit and connection patterns.

A wide variety of components can be accommodated on the printed substrate, including ceramic and tantalum chip capacitors and leadless chip carriers containing up to 68 connection pins (this capability will shortly be expanded to accommodate larger chip carriers with up to 84 pins). The chip carriers referred to here are rectangular in shape and have connection pads located along all four sides spaced at pitch intervals of 1 mm or 1.27 mm.

A particularly valuable advantage of packaging ICs inside chip carriers is that it enables them to be fully tested and qualified prior to being mounted on the ceramic circuit board.

## Easier flux clearance

Once the ICs and components have been assembled on the board they are restrained by an elastomeric fixative and then soldered into position by the technique of reflow soldering. Because the body of the chip carrier is made from a ceramic material similar to that from which the circuit substrate is made, it has similar thermal characteristics and the soldered joints are not subjected to significant thermally induced stresses.

The process developed by the Micro-electronics Technology Centre for the attachment of components to circuit boards results in a controlled stand-off (board clearance) height for the mounted components of about 380 mm.

The advantages that come from such a clearance are that they ease the clearing of flux residues from under the components and make possible the close inspection of solder joints by either normal visual means or new techniques such as X-ray microfocus. This type of inspection is not possible without stand-off height.

The complete clearance of flux residues is highly desirable since the presence of such contaminants can pose a serious risk to long-term reliability.

External connections to the circuit board are made by a surface-mounted connector with soldered joints formed by reflow soldering.

There are essentially two methods of assembly adopted by the Micro-electronics Technology Centre. The first makes use of a single sided board fitted with metal edge supports so that the ceramic board can be inserted directly into a standard Eurocard rack. The second method takes advantage of the good thermal conductivity of the aluminium oxide ceramic substrate and uses it as a heat sink for two fully assembled ceramic boards mounted back-to-back on either side of an aluminium core plate.

## Punishing tests

The plate functions as both a structural support and a very efficient heat sink. This form of assembly is used where space is restricted. The heat-removing properties of the assembly are further enhanced by the use of high thermal conductivity material for the elastomeric adhesive employed for component placement and for attaching the boards to the core plate.

Circuit board assemblies using the back-to-back method of mounting have been subjected to an independent series of tests carried out by the Components Evaluation Department of British Aerospace's Air Weapons Division.

The tests, which are punishing to any electronic assembly, have included operating temperatures ranging from −55 °C to 125 °C; damp heat storage at 85% relative humidity at 85 °C for 1000 hours; a one minute acceleration of a gravitational force (g) of 1000 (9806 metres per second per second); 400 temperature cycles ranging from −55 °C to 125 °C with ten minutes dwell time and five minutes transfer time; and 100 cycles of ambient power cycling for 15 minutes each side when dissipating 130 mW/cm². As if this was not enough, low frequency power cycling was imposed at 130 mW/cm², and switched on and off repeatedly for 20 temperature cycles.

## Automated manufacture

In addition, high frequency power cycle was superimposed on 70 temperature cycles while power at 130 mW/cm² was switched on and off at one minute intervals.

In addition to its design and manufacturing capabilities at Hatfield, the Micro-electronics Technology Centre can also undertake the modification and repair of fully assembled boards. It can, for example, remove and replace all sizes of leadless chip carriers, chip capacitors, chip resistors and flat conductor cable, and cut and isolate copper track.

Work is under way to commission an automated production facility dedicated to the manufacture of copper-on-ceramic multi-layer modules using the operating experience acquired from the company's existing design and manufacturing service.

Micro-electronics Technology Centre, British Aerospace PLC, Air Weapons Division, Manor Road, HATFIELD AL10 9LL.

# BREAKTHROUGH IN SUPERCONDUCTING MATERIALS

by Peter Hartley, MIMGTechE

**One of the technological sensations of the past eighteen months has been the race towards the first effective room temperature superconducting material. Apart from achieving reliability, one of the major problems is how to fabricate useful products on a commercial basis from the new breed of ceramic materials.**

Basic Volume [(1)], a specialist sensors and electronics materials company, claims to have produced the world's first superconducting solenoid in a ceramic material. This development could start an avalanche of applications for superconducting ceramics.

Superconductivity, the phenomenon in which a material loses all its resistance to electric current, was until comparatively recently observed only at temperatures below −250 °C. This required the use of liquid helium as a coolant.

In February 1987, however, Dr Paul Chu at the University of Houston in the United States discovered a ceramic compound that superconducts at −183 °C, consisting of yttrium, barium, copper and oxygen. This opened up the possibility of using liquid nitrogen, which boils at −196 °C and is much cheaper to use than helium as a coolant.

## Single-turn solenoid

Basic Volume, which manufactures solid-state chemical sensors and signal process electronics, was actually producing some of the materials used for superconductivity researches enabling the company's Dr Tim Tavares and his team to experiment with materials that were available immediately.

In March 1987, the company was able to produce samples of $Y_{1.6}Ba_{0.4}CuO_{4-x}$ with a superconductivity transition temperature of −213 °C, and this was rapidly improved upon with its so-called YBC0123 compound in April.

On 24 April, after three previously unsuccessful attempts, the company managed to produce a ceramic superconducting single-turn solenoid. This was made of YBC0123, measured 90 mm long with a 14 mm outside diameter and a radial thickness of 3 mm. The device's material was also, unlike some other similar materials, stable in water.

This development means that many commercial applications of the new nitrogen-cooled ceramic supercon-

ductors are months rather than years away. Among the uses immediately envisaged are: nuclear magnetic resonance equipment, magnetic mineral separation, magnetic bearings, high torque dc electric motors, spin resonance spectroscopy equipment, and electronic imaging apparatus.

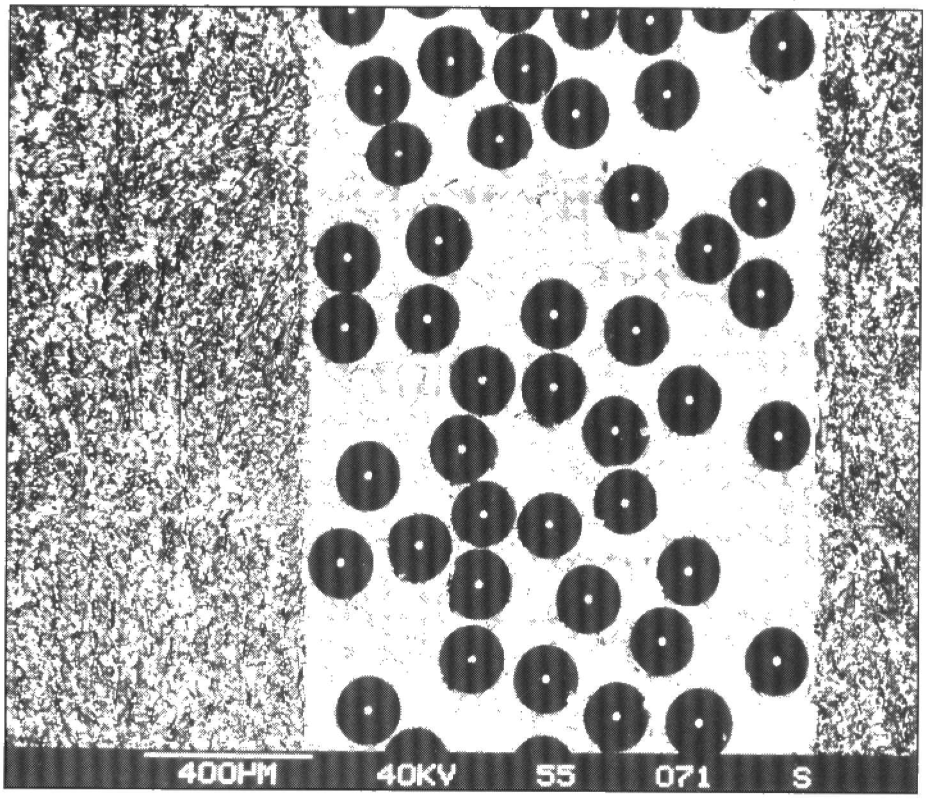
## Metal matrix composites

Dr James Watson of Southampton University, a specialist in the magnetic separation of minerals, has been supplied by Basic Volume with tubes of $YBA_2\ CU_3\ O_{6.5\text{-}7}$ superconducting ceramic. These tubes, which are 37 mm in diameter, 90 mm long and 1 mm thick, superconduct reliably at temperatures up to −196 °C.

He finds that the material supplied to him by Basic Volume provides a much higher density than competitive products — 90% of the theoretical maximum — and allows current carrying capacities up to $5 \times 10^4$ A/cm².

Superconductors may have made the technological headlines during the past year, but an equally exciting engineering materials development has been that of the commercialization of metal matrix composites.

To most engineers, the word composites conjures up the image of plastics reinforced with glass or carbon fibres. In these materials, the fibres confer strength to an otherwise mechanically weak material. The fibres take the load and the polymer matrix serves to distribute this load equally between them.




**A metal matrix composite containing a hybrid of short 3 μm diameter alumina fibres and silicon carbide coated boron fibres.**

## Large capacity production

The same principle is used in a family of new materials — metal matrix composites (MMCs) — in which a metallic phase (the matrix) is reinforced by very strong ceramic or metal fibres, whiskers or particles.

In 1984, the British Collyear Committee Report on new engineering materials and processes states that the key areas for development in MMCs were concerned with the technology of producing them in tonnage quantities.

This is an aim towards which the Metals Technology Centre at the Harwell Laboratory [2] is deeply committed. The so-called MMC Club, organized by, and centred on, Harwell, is carrying out research into titanium-based MMCs within the framework of the European Community's BRITE (Base Research in Industrial Technologies) programme.

Cray Advanced Materials [3], backed by the Cray Electronics Group, was formed some 18 months ago to exploit MMCs commercially. The company operates under a licensing agreement from Britain's Ministry of Defence and uses the patented liquid pressure forming (LPF) process, a new technique for making components from fibre-reinforced metals.

## Producing complex shapes

Commercial applications of MMCs, currently at the feasibility demonstration stage, include: components for the automotive industry such as pistons, connecting rods, brake callipers, and wheels; gas cylinders; marine propellers; armour plate; lead battery plates; bicycle frames; robotic arms; overhead pantographs for electric trains; and specialist tools.

The LPF process is a technique for the production of ceramic fibre-reinforced metal components to net shape or near net shape, with excellent dimensional tolerances and exceptional mechanical properties.

Various types of ceramic fibre, such as silicon carbide, alumina, boron and carbon, can be used with metals such as aluminium, magnesium, lead zinc or copper alloys.

The Cray LPF process can be used to produce complex shapes that vary in size from a few centimetres up to 2 m × 1.5 m × 1.5 m. It is essentially a single-batch process that produces a net-shaped reinforced component with tolerances in the region of ± 0.2%. Production times are relatively short and die costs low for the volume output.

## Glass ceramics

Ceramic Developments (Midlands) Ltd (CDML) [4] is carrying out a range of investigations into the engineering applications of glass ceramics. These differ from true glasses in being polycrystalline ceramics resulting from the crystallization of glasses.

They differ from traditional engineering ceramics in that the starting material is nearly always completely amorphous and not the product of the liquid phase sintering of ceramic precursors.

CDML has carried out an internal development programme aimed at producing a range of photomachinable glasses and glass ceramics with differing expansion coefficients in the range $7 \times 10^{-6}$/°C to $11 \times 10^{-6}$/°C.

Augmented by CDML—funded research at Sheffield University this has led to the development of a useful range of materials with potential for:

- micro-electronics substrates where high densities at fine holes are needed for interconnection;
- plasma display panels;
- competition with low volume production of ceramic components but giving higher precision without prohibitive tooling costs.

## Potential applications

The Department of Trade and Industry has recently awarded the company a

grant of £28,000 to further this project. Glass ceramics developed at CDML show abrasion resistances comparable to that of boron carbide. Potential applications for this material are pipe linings, the coatings for moving parts operating in abrasive environments, and possibly the plasma spraying of large metal components in situ. According to Dr Ronald Jones, CDML's managing director and founder, the firm is now at the stage of being able to cast glass ceramic pipes centrifugally.

One of the most impressive results of work at CDML has been the successful development of glass ceramic armour that shows a similar ballistic performance, thickness-for-thickness, to that of alumina, when used as a protection against 7.62 mm calibre rifle bullets.

The real advantages, however, are weight saving — since the ceramic glass has a density of only 2.4 g/cm$^3$ as opposed to 3.8 g/cm$^3$ for alumina — and relatively low processing costs.

## Screening equipment

A further useful development at CDML has been the production of very high-quality glasses and glass ceramics by Sol-Gel technology. This involves polymerizing the silicate networks from ethoxysilanes by condensation polymerization. The resultant glasses have a very high surface area tension and can be densified by heat treatment at about 500 °C. This enables glass to be made for catalyst supports, barrier layers and coatings, which are almost impossible to produce by conventional fusing of oxides.

CDML is also researching the use of glass ceramic materials for use as strong, heat-dissipating substrates for thick-film circuitry. The company has formed a consortium with Thorn-EMI, Lucas, Wade and Engelhard, to develop and exploit its work in this area.

Another area of United Kingdom electronics materials development has been in the field of screening equipment against electromagnetic interference (EMI) and radio frequency interference (RFI). Thus, in anticipation of new and tougher European Community legislation on allowable levels of electromagnetic noise emissions from equipment, Shipley Europe [5] has introduced a new EMI shielding technique based on the firm's well established electroless plating technology.

## Longlasting adhesion

The chemical process involved deposits uniform thicknesses of copper and nickel coatings on all component surfaces to give, it is claimed, a 40 dB improvement in attenuation of EMI over previous methods such as arc spraying of zinc or the use of conductive nickel paints.

Since copper is a better electrical conductor, it provides maximum protection with a fraction of the thickness used with other methods, resulting in lighter fabrications and greater cost savings. Shielding effectiveness is greater than 80 dB with a copper thickness of only 625 $\mu$m.

Total immersion in a series of chemical treatment baths ensures that all surfaces, no matter how complex, receive a uniform coating of metal. Pre-cleaning and etching give long lasting coating adhesion and ensure, it is claimed, that electroless shields will not crack or flake the way some arc sprayed zinc coatings can.

The process can be used for both solid injection moulded plastics parts and structural foam plastics components, made from ABS, polycarbonate, polypheylene oxide, polystyrene and many other polymers. A final coating of electroless nickel protects against corrosion, abrasion and provides a suitable base for cosmetic finishing.

## Elastomeric gaskets

Dowty Seals [6] claims to have achieved a breakthrough in EMI/RFI screening with its new Dowshield range of conductive elastomeric seals and gaskets. This range incorporates seven different compounds and three types of seals — Dowprint, moulded seals and extruded profiles.

Four of the compounds are used specifically for the production of flat elastomeric gaskets by the company's Dowprint screen printing process. For this, there is a choice of silicon or cross-linked vinyl polymers, loaded with conductive silver or silver-plated nickel particles. They provide a volume resistivity as low as 0.0004 Ω/cm and a signal attenuation as high as 106 dB by the American Society for Testing Materials (ASTM) test method.

The moulded seals and extruded components employ silicon or fluoro-silicon materials loaded with silver-plated nickel.

## Radiation dosemeter

Another interesting innovation on the plastics front is the development of 20% and 30% glass fibre-reinforced, nuclear radiation resistant, polyethersulphone — Victrex PES — by ICI [7].

The British custom-moulding company, Jarzon Plastics [8] has added these materials to its range of engineering plastics. It has collaborated with the GEC company to design and produce nuclear radiation dosemeters — worn on the wrist — in one of these materials, which allows gamma rays to penetrate.

After exposure to radiation, the dosemeters are slotted into a drawer of the same material, which in turn is slotted into a reader to obtain the radiation level readout.

**References:**

1. Basic Volume Ltd, 13a Cotswold Street, London SE27.

2. Harwell Laboratory, Harwell, Didcot, Oxfordshire OX11 0RA.

3. Cray Advanced Materials Ltd, 6 Armoury Road, Lufton Trading Estate, Yeovil, Somerset BA22 8RL.

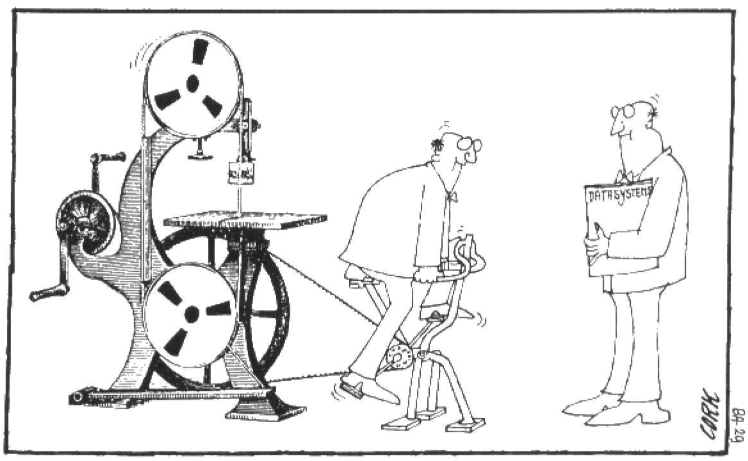
4. Ceramic Developments (Midlands) Ltd, St Marks Road, St James Industrial Estate, Corby, Northamptonshire NN18 8AN.

5. Shipley Europe Ltd, Herald Way, Coventry CB3 2RQ.

6. Dowty Seals Ltd, Ashchurch, Tewkesbury, Gloucestershire GL20 8JS.

7. Imperial Chemical Industries PLC, Petrochemicals & Plastics Division, PO Box 6, Bessemer Road, Welwyn Garden City, Hertfordshire AL7 1HD.

8. Jarzon Plastics Ltd, Golden Crescent, Hayes, Middlesex UB3 1AQ.



# TEST & MEASURING EQUIPMENT

# Part 2: Digital Storage Oscilloscope

by Julian Nolan

**The Federal German firm of Hameg is one of the best known manufacturers of low-cost oscilloscopes. Their recently revised range of scopes includes the HM205-2 digital storage model, chosen for this month's review.**

Hameg's revised range of oscilloscopes extends from the HM203-6 dual-trace, 20 MHz instrument to the HM208 dual-trace, 20 MHz sampling rate digital storage model. Options include an IEEE-488 bus and graphic printer, which is compatible with the HM205 and HM208.

The HM205-2 is an uprated version of the earlier HM205 and offers a 5 MHz per channel sampling rate, dot join facility and DC-20 MHz bandwidth when used as an analogue instrument. The HM205 and HM205-2 are based on the HM203-6, so that the parts of this review not dealing with the digital facilities of the HM205-2 are also relevant to the HM203-6.

The HM205-2 is supplied complete with 2 probes and retails at £527, excl. VAT. It is of compact design, measuring $285 \times 145 \times 380$ mm (W×H×D), and is immediately recognizable as a Hameg instrument by its moulded plastic front surround and techno-brown enclosure. The layout of the front panel is fairly conventional, apart from the inclusion of a group of 6 push-buttons for the control of the digital storage functions. The front panel of the HM205-2 has been redesigned to some extent as compared with the earlier model because of the removal of the graticule illumination and the inclusion of a more comprehensive storage and TV trigger facilities. The instrument is fitted with a swivel stand that easily locks in a convenient number of positions, and is generally much easier to operate than that on many competitive instruments.

Mains voltage selection is externally switchable between 110 VAC and 240 VAC. Power consumption at 42 watts is, perhaps, a little on the high side, considering the HM205-2's accelerating voltage of 2 kV.

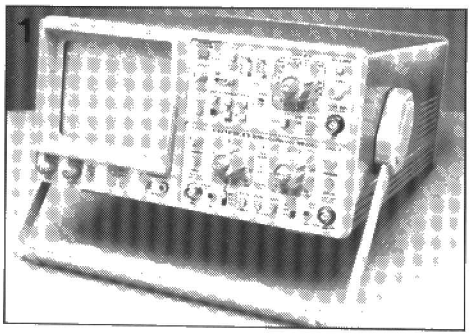


Fig. 1. General view of the Hameg HM205-2.

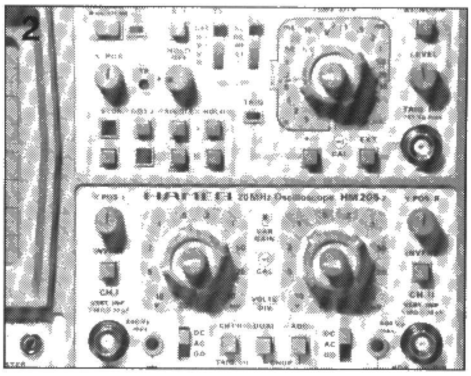


Fig. 2. Close-up of front panel of HM205-2.

## Analogue operation

**Y-amplifiers.** The input capacitance of the Y-amplifiers is somewhat high: 30 pF, which is some 10 pF higher than that on some competitive instruments. This should, however, not cause any problems for most purposes.

In common with those on other German-made oscilloscopes, the variable controls increase sensitivity to a maximum of about 2 mV/div: maximum calibrated sensitivity is 5 mV/div. A good range of deflection coefficients is provided. The minimum sensitivity is 20 V/div, which enables relatively high voltages to be measured without the use of a :10 probe.

Ringing and rounding are kept to reasonable levels, and overshoot is minimal. The dynamic range of both Y-amplifiers is good: 8 divisions at 20 MHz. At frequencies above this, the dynamic range, as might be expected, decreases quite dramatically and is virtually non-existent above 65 MHz.

In terms of frequency-dependent attenuation, both Y-amplifiers perform well: the −3 dB point lies well over the specified 20 MHz. Unusually, both channels can be inverted, allowing easy addition or subtraction of waveforms from either channel.

Chopped (500 kHz) or alternate modes are selected manually by a group of 3 push-buttons that also incorporate Chl/Ch2; trigger 1/2; and add modes. Owing to the large number of functions incorporated, operation of these controls can be tedious.

Also incorporated is a calibrator, which may be switched between 2 V and 0.2 V outputs. With a rise time of 3 ns, this facility is useful for functions outside that of probe compensation.

**Triggering.** The HM205-2 is equipped with a fairly comprehensive range of triggering facilities, including LF and HF filtering, positive and negative TV synchronization, and trigger hold-off. A notable absentee here is alternate channel sourcing: stable display of synchronous signals is, therefore, possible only in the dual trace mode.

Triggering is generally reliable and operation is aided by a LED status indicator. In automatic (bright line) mode, the triggering level is set at constant. While this is perfectly acceptable if the instrument is AC coupled, with DC coupling it means that only signals with a zero crossing point can be measured, unless the instrument is set to normal mode. Also, if, for instance, it is desired to trigger on, say, the lower part of the rising edge of a waveform, the scope again must be set to normal mode. TV mode triggering is effective on both positive and negative synchronization video signals. The inclusion of trigger hold-off

enables the triggering on complex waveforms, irrespective of the timebase speed.

Triggering bandwidth and sensitivity are good: the sensitivity is a 1/2 division up to 40 MHz. External sensitivity is 0.3 V up to 40 MHz. The maximum trigger frequency appears to be about 70 MHz, although, as stated earlier, the dynamic range is virtually non-existent at this frequency.

**Timebase.** In common with some other 20 MHz oscilloscopes, a range of 500 ns to 0.2 s per division is covered by the analogue timebase. The deflection speed may be extended to 50 ns/div when the timebase is calibrated, or to 20 ns/div when the timebase is uncalibrated, with the aid of the $\times 10$ magnifier. Accuracy is typically $\pm 3\%$ and $\pm 5\%$ with and without the magnifier respectively.

Linearity is good throughout all the timebase speeds and complements the good overall timebase performance. As with the Y-amplifiers, it might have been useful to decrease the speed with the continuously variable control rather than increase it. This would have allowed a maximum calibrated sweep speed of 20 ns/div, which would obviously be more accurate than the corresponding speed set by the preset.

**CRT.** The performance of the cathode ray tube is very much like that of other 2 kV tubes and should be acceptable for most purposes. Although not outstanding, it offers a good level of brightness coupled with relatively sharp focusing. A good and fairly even level of brightness is maintained over all sweep speeds, including $\times 10$ magnification. At the higher brightness levels, should these be needed, some refocusing is necessary, although only to a small extent.

While both pincushioning and barelling are kept well within reasonable limits, tube geometry is a little less certain, with noticeable defocusing occurring at either end of the trace. This is, however, not severe and does not affect measurement accuracy.

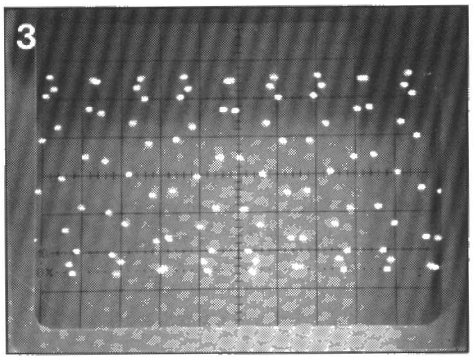



**Fig. 3. Storage mode, $\times 10$ magnification, with dot join facility inoperative.**

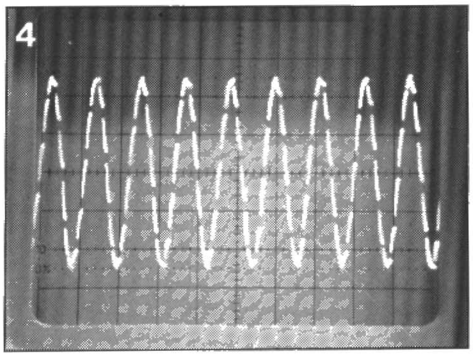



**Fig. 4. As Fig. 3 but with dot join facility operating.**

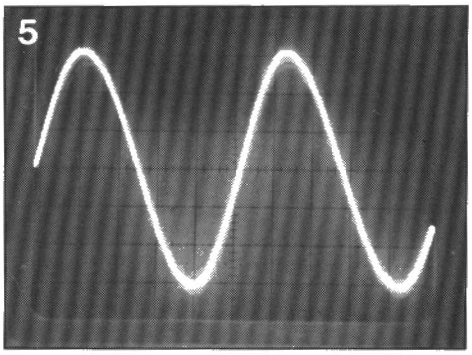



**Fig. 5. Storage mode with $\times 10$ magnifier inoperative.**

## Digital storage modes and features

The HM205-2 offers four main operating modes: refresh, single shot, hold Ch1 and hold Ch2. The refresh mode enables the screen to be constantly updated and prevents the flicker associated with lower sweep speeds. In single-shot mode, the instrument triggers once on the incoming signal; a reset button is provided for resetting the sweep. The other two functions are self explanatory.

One of the main criteria of any storage scope is its sampling rate. In recent years, in spite of lower prices, this has steadily increased. Lower prices have largely been brought about by the dramatic fall in costs of flash A-D converters and storage SRAMs. Considering that before the introduction of the HM205-2 digital storage oscilloscopes with a 2 MHz sampling rate, or better, cost at least £1,500, the HM205-2's sampling rate of 5 MHz per channel provides an excellent price/performance ratio.

Digital storage is particularly advantageous for the measurement of low-frequency and non-recurring signals. Although the HM205-2 meets the requirements for such measurements with its single-shot and refresh modes, it would have been helpful if some sort of pre-trigger facility had been provided. However, considering the HM205-2 price, only about £200 more than the non-storage HM203-6, it is, perhaps, not surprising that the instrument lacks some of the facilities of its more expensive rivals.

Owing to the absence of sine or pulse interpolation facilities, the maximum practical measurement frequency is about 500 kHz, compared with the theoretical Nyquist frequency of 2.5 MHz. The 500 kHz range allows for 256 points per cycle which, coupled with the dot join facility, enables a reasonable reconstruction of a sine wave to be achieved. The dot-joint facility itself enables the joining of adjacent points, creating the effect shown in Fig. 3 (worst case example; $\times 10$ magnification on). Some frequency-dependent attenuation is noticeable at frequencies above 300 kHz, but this does not seriously affect the response until frequencies above 600 kHz are reached.

The A-D converters appear to have good differential linearity, although the vertical resolution is obviously limited to 256 points. The vertical resolution of 8 bits is accepted almost universally in low-cost DSOs as the best trade off between speed, resolution and price. The total on-screen calibrated vertical resolution of the HM205-2 is 28 points per division, while the corresponding horizontal resolution is 1024 points, or 100 points per division on both traces. The horizontal resolution should prove to be acceptable for most purposes when the trace is not magnified. However, with the trace magnified $\times 10$, some waveforms are difficult to distinguish without (and sometimes even with) the dot join facility in operation. The instrument would have benefited from the extra resolution afforded by a 2 K or 4 K point horizontal resolution system. Per channel, 1 K or memory storage is provided, bringing the total memory to 2 K, enabling the storage or recall of up to 2 traces.

Digital storage timebase speeds range from 5 s/div to 2 $\mu$s/div, and these can be magnified with the $\times 10$ deflection magnifier. These timebase speeds should be adequate for most purposes, with the total capture time ranging from 50 s to 20 $\mu$s. Overrange timebase operation is indicated both audibly and visually, insuring against the possibility of false measurements.

As already mentioned, a single-shot triggering facility is available, which allows the capture of non-repetitive events, such as switch debounce or digital pulse trains. In addition to this extremely useful feature, the normal trigger facilities are also available, as in the analogue mode.

## Component tester

This well-established feature of Hameg oscilloscopes allows the checking of components by the display of a V-I curve of the device under test. For example, a right angle is produced for a typical semiconductor junction, while a straight line can be expected for a resistor. The test voltage is 8.5 $V_{rms}$, which makes it compatible with a wide range of compo-

nents. Complete circuits may also be tested if the response that may be expected is previously known. Overall, the component tester is proved to be genuinely useful in providing a very quick and clear indication of whether a component in serviceable, along with, in most instances, an indication of its value.

## Construction

The complexity of the HM205-2 causes its innards to be rather cramped and this may prove troublesome when the instrument has to be serviced. Having said that, all six PCBs are of epoxy glass and construction is of a high standard for an instrument in this price range. Ribbon cables and IDC connectors are used throughout the instrument. All this indicates that a good level of reliability should be expected. Accessibility is particularly difficult around the PCB housing the A-D converters, control logic, and memory, which is sandwiched between the boards containing the analogue circuitry.

Externally, the instrument is also constructed to a high standard. The enclosure is made from sheet steel with plastic front and back panels. It is worth noting that, as on so many oscilloscopes, some of the controls protrude some distance from the front panel and might be easily damaged in some environments.

## Manual

The HM205-2 is supplied with a good manual, which contains extensive sections on applications and the initial setting up of the instrument. Detailed circuit diagrams and a circuit description are also provided.

## Conclusion

The HM205-2 offers good value for money in its combination of a 5 MHz sampling rate per channel, dot join facility, and refresh mode with a highly specified 20 MHz analogue oscilloscope. The DSO functions worked well and met their specified limits, as did the instrument in the analogue mode.

The performance of the tube was good, with above average grades of brightness available at reasonable focusing levels.

The standard of construction is very good and should enable the instrument to work successfully in a wide range of environmental conditions.

The Hameg HM205-2 was supplied by **Hameg Ltd • 74-78 Collingdon Street • LUTON LU1 1RX • Telephone (0582) 413174.**

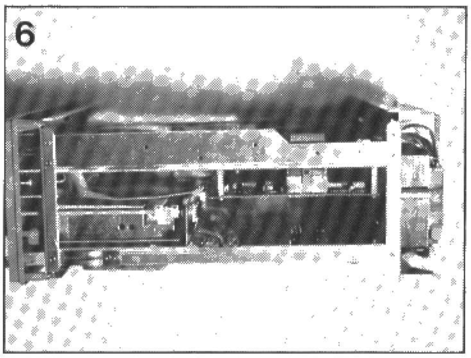


**Fig. 6. Internal side view of HM205-2.**

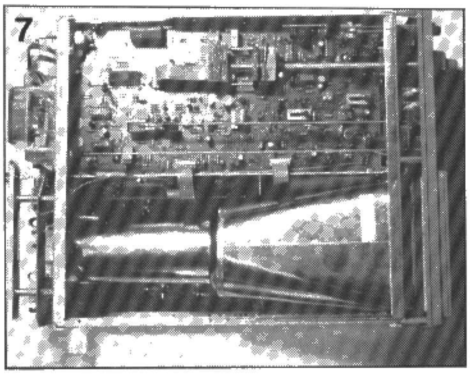


**Fig. 7. Internal view from top.**

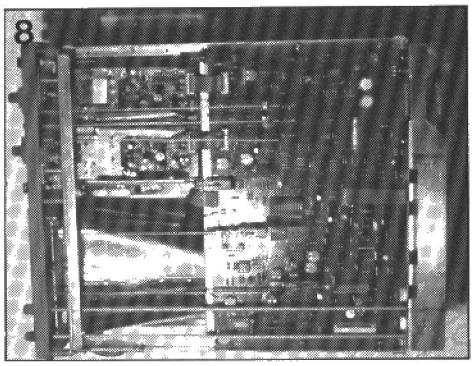


**Fig. 8. Internal view from underside.**

Other oscilloscopes available in the Hameg range.

**Analogue:**

**HM203-6** — dual trace; 20 MHz; 2 mV sensitivity; component tester; triggering to 40 MHz; active TV sync; 2 kV CRT; £314 excl. VAT.

**HM606** — to be introduced shortly; 60 MHz bandwidth; three Y-amplifiers (1 with fixed deflection coefficient); max. 1 mV sensitivity; dual timebases; maximum of 6 traces; full TV triggering facilities; retail price not yet available.

**Digital:**

**HM208** — 20 MHz sampling rate; 1 mV sensitivity; roll and refresh modes; pen recorder output; 4 K storage memory; IEEE option; 14 kV CRT; £1,460 excl. VAT.

**Table 1.**

SUPPLY REQUIREMENTS
Mains voltage: 110-125-220-240 VAC ±10%, externally adjustable: frequency 50/60/400 Hz.
Power consumption: 30 W.

MECHANICAL CONSTRUCTION
Dimensions: 285 × 145 × 380 mm (W × H × D).
Housing: steel sheet.
Weight: approx. 8 kg.

Y/AMPLIFIER
Operating modes: CH1 or Ch2 alone — inversion capability on both channels; dual Ch1 and Ch2 (alternate or chopped — 500 kHz); Ch1 + Ch2.
Frequency response: DC to 20 MHz (−3 dB).
Rise time: 17.5 ns
Deflection factor: 12 steps — 5 mV/div to 20 V/div ±3% vernier control adjusts max. sensitivity on 5 mV/div range to about 2 mV/div (fully cw).
Input coupling: AC, DC, or GND.
Input impedance: 1 MΩ/30 pF.
Maximum input voltage: 400 (DC + peak AC).

X-Y mode
Channel 1: Y axis.
Channel 2: X axis.
Bandwidth: DC to 2.5 MHz (−3 dB).
X-Y phase difference: 3° at 120 kHz.

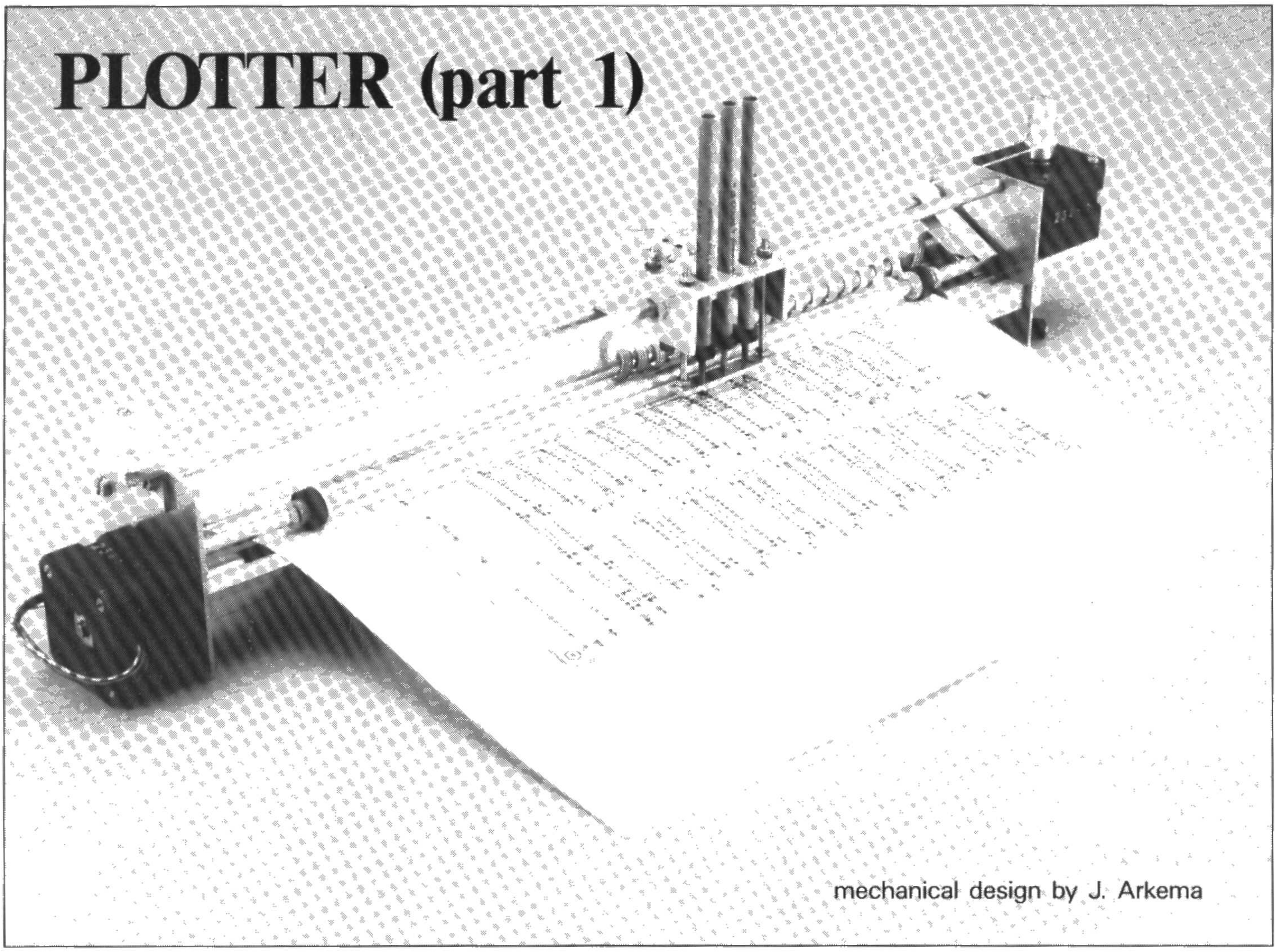
SWEEP
Sweep time: 50 ns/div to 0.5 s/div ±3% in 17 ranges at 1-2-5 sequence; vernier control increases sweep to 200 ns/div.
Sweep magnification: ×10 ±5% on all ranges.
Hold off: variable up to 10:1.

TRIGGERING
Trigger modes: auto (bright line + fixed level), normal.
Trigger coupling: AC, DC, HF and LF reject, TV frame and line.
Trigger sources: Ch1, Ch2, Line, Ext., vertical (alternate).
Triggering sensitivity: internal 0.5 div. at 40 MHz; external 0.3 $V_{pp}$ at 40 MHz.

MISCELLANEOUS
CRT: make HAMEG; measuring area 80 × 100 mm; accelerating voltage 2 kV.
Compensation signal for divider probe: 2 $V_{pp}$ or 0.2 $V_{pp}$ ±1%; frequency 1 kHz.
Vertical Ch1 or Ch2 output: approx. 50 mV/div into 50 Ω.
Covered by 1 year warranty.

DIGITAL STORAGE SECTION
Operating modes: refresh and single (with reset and ready LED); hold Ch1 and Ch2; dot joiner.
Memory size: 1024 × 8 bit for each channel.
Sampling rate: max. 5 MHz for each channel.
Resolution: vertical 28 samples/div; horizontal 100 samples/div.
X expansion: ×10 (X resolution 10 samples/div).
Options: analogue/digital output for Hameg Graphic Printer or X-Y Recorder.

# PLOTTER (part 1)




**Many owners of a personal computer and associated peripheral equipment will at some time have wished that graphics information available on screen could be sent to a plotter instead of a slow, noisy printer operated in the dot-matrix mode. But then, even the simplest of plotters is often more expensive than the computer itself.**
**Not so the plotter described here, which is a unique project: fairly simple to build, complete with a versatile and power-efficient stepper motor interface driver, available in kit form, and offering a good price/performance ratio. The final accuracy of the plotter should be adequate for a host of graphics applications, and depends mainly on the constructor's mechanical skills.**

Matrix printers are fine for text applications, but can not handle graphics information very well. They are invariably slow because in the bit image mode pixels are printed one line at a time. In addition, their resolution is insufficient for many applications, they are noisy, and only very few types can handle large sheets of paper (A2; A3).

The plotter described here is not of the X-Y type commonly found in the least expensive class of commercially available plotters, but is similar to a standard text printer in that it has a pen carriage for the horizontal (X) direction, and a platen (paper roller) for the vertical (Y) direction. This approach makes it possible to keep the mechanical construction relatively simple, while allowing many paper sizes to be used. The platen is driven direct by a stepper motor; the pen carriage indirect by a string and a second stepper motor. Arguably, in the absence of an absolute X-Y reference point, this arrangement has the disadvantage of being subject to accumulative positioning errors. Fortunately, deviations caused by these errors can be kept small in practice by ensuring that the paper and the carriage are not obstructed in their respective movement.
Small electro-magnets are used for lifting and lowering the three pens. These are simply refills available from bookshops and warehouses, and come in various colours for many types of inexpensive drawing pen. The pen carriage on the plotter is shown in the photograph of Fig. 1.

The stepper motor interface board for the plotter can be driven by an 8-bit Centronics port, which is a standard outlet available on the majority of modern computers. Control bits are arranged in a manner to enable direct connection of the Centronics port to the plotter interface board via a length of flat ribbon cable. The control circuit has been designed for efficient powering of the stepper motors and pen magnets. The power supply, exclusive of the mains trans-

former, is accomodated on the interface board to make for a compact and simple to connect unit.

## Mechanical construction

The plotter is essentially a beam construction as shown in Figs. 2a and 2b. Two aluminium support plates (60×70×2 mm) at either side hold the complete assembly in between them. The stepper motors are secured to the outside of the plates. Three round bars (dia. 6 mm solid aluminium or stainless steel tubing), and one square bar (10×10 mm aluminium) are fitted between the support plates. The length of the bars determines the maximum paper size, and can be dimensioned to individual requirement. A length of 508 mm, for example, enables sideways drawing on A2 size sheets of paper, often used in the graphics industry.

Details on the construction of all the mechanical parts for building the plotter are shown in the working sheet of Fig. 3. The paper roller is a round aluminium rod (spindle) of 12 mm diameter fitted immediately behind the square bar. Good grip on the paper sheet is ensured by reducing the diameter of the platen a few tenths of a millimeter over two lengths of 30 mm by turning in a lathe, and covering these areas in very fine sandpaper, wound spirally and glued onto the aluminium surface. Every precaution should be taken to prevent the total diameter of the platen increasing where the sandpaper is secured. Two pressure rollers, fitted on a movable axle, rest on the sandpaper grips (see Fig. 4). To insert or remove a sheet of paper, the axle can be lifted by means of two small tilt levers made from aluminium U-beam. The rollers are firmly pressed onto the paper by the pull of two small springs.

The platen is driven direct by a stepper motor with a step size of 200 per revolution. At the indicated platen diameter of 12 mm, this results in a resolution of 0.19 mm/step. Half-step operation is also supported by the driver board, increasing the attainable resolution to slightly less than 0.1 mm.

The pen carriage is in essence a short length of aluminium U-beam. The guide rod runs through nylon slide bearings (Skiffy) secured in holes drilled in the legs of the U. Tilting of the pen carriage is prevented by its rear side resting on another rod. Carriage movement on the guide bar is effected with the aid of a string. This is wound one and a half turn around a shaft, up to the height of the securing screw, and then a further six to ten turns upwards. The shaft is made from the same material as the platen, and is fitted onto the spindle of the stepper motor. For optimum accuracy, the total diameter of the shaft plus string should equal that of the platen (12 mm).

1

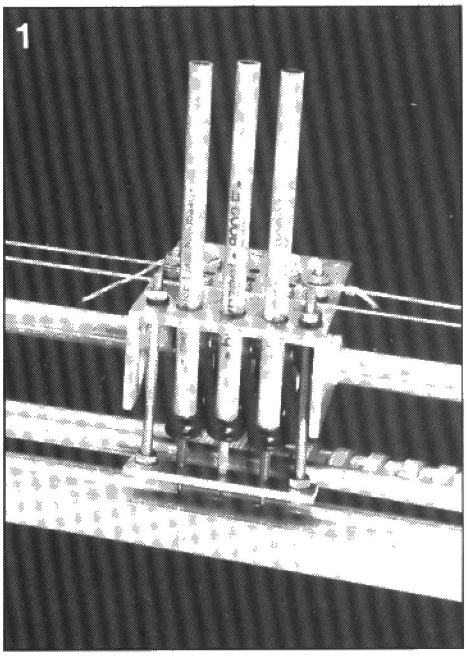
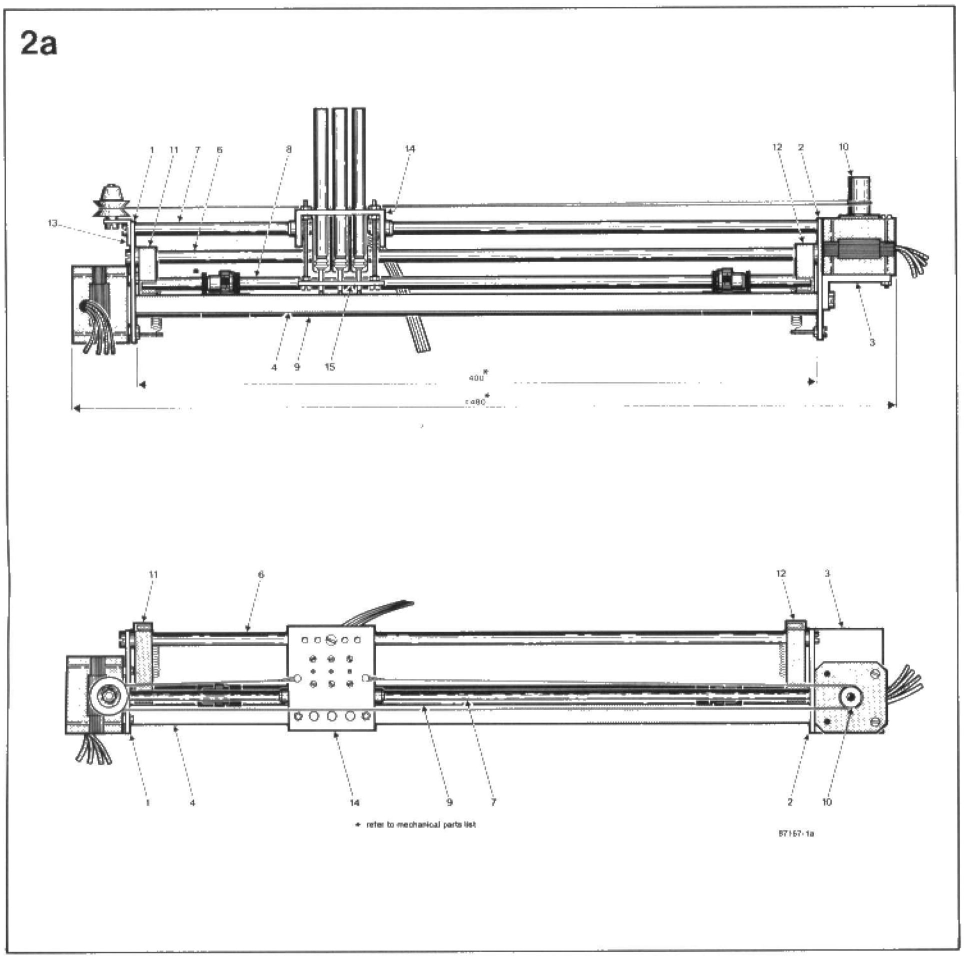


**Fig. 1. The movable carriage on the plotter holds three pen refills in different colours. Not visible in the photograph are the associated electromagnets for pen up/down control.**

This ensures equal pen travel per step in the X and Y direction. Each pen is guided through a hole drilled in the top of the U-beam, while the tips are kept firmly positioned on or above the paper with the aid of a support plate. The square aluminium bar in front of the



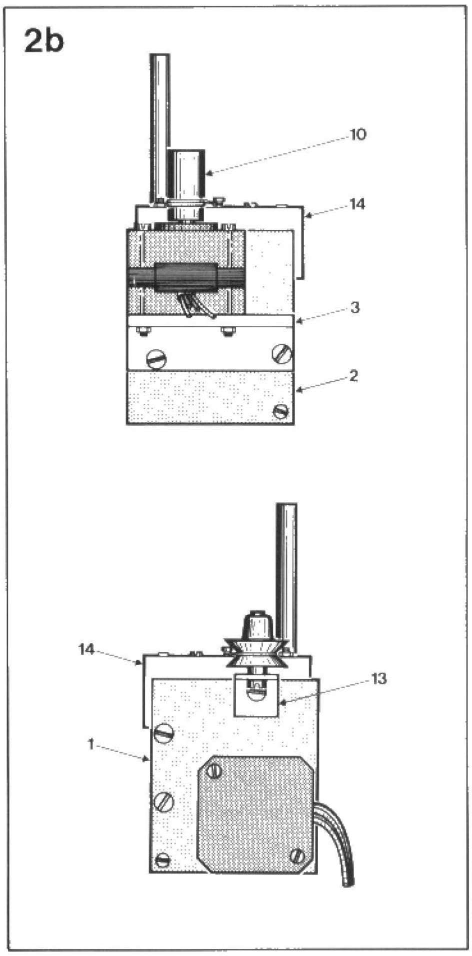


**Fig. 2. Working drawings of the assembled plotter seen from the front and top (a) and from the sides (b).**

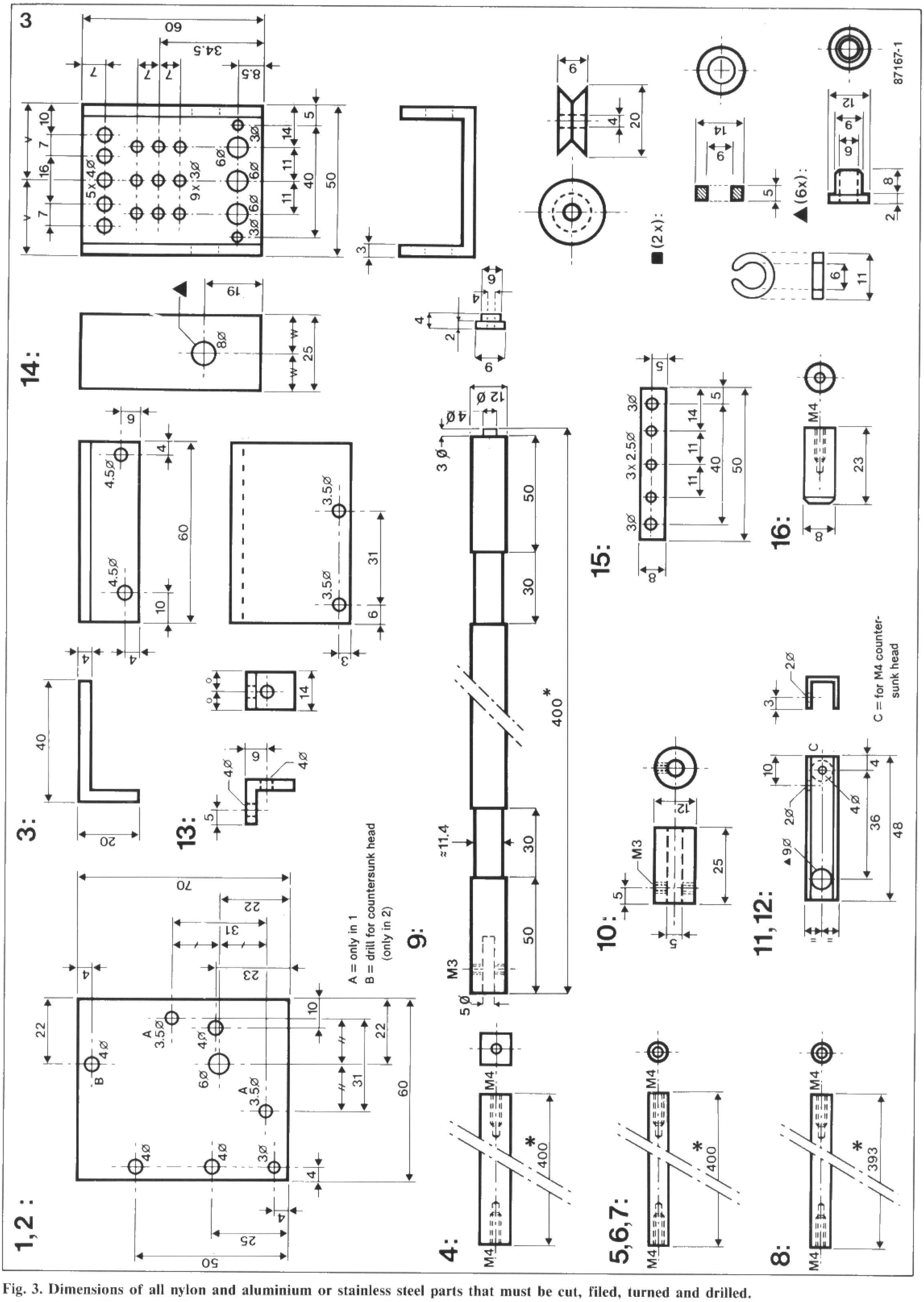



**Fig. 3. Dimensions of all nylon and aluminium or stainless steel parts that must be cut, filed, turned and drilled.**

**Mechanical Parts list**

1. side plate; left; aluminium; 60×70×2 mm.
2. side plate; right; aluminium; 60×70×2 mm.
3. angled support bracket for X motor; L-shaped aluminium; 20×40×4 mm; length 60 mm.
4. square connection bar; aluminium 10×10 mm; 400 mm long*.
5. round connection bar; aluminium/stainless steel rod; dia. 6 mm; 400 mm long*.
6. round support bar for pen carriage; dimensions as 5).
7. round guide bar for pen carriage; dimensions as 5).
8. round bar for pressure rolls; aluminium/stainless steel rod; dia. 6 mm; length 393 mm*.
9. platen; round aluminium bar; dia. 12 mm; length 400 mm*.
10. shaft; aluminium; dia. 11.2 mm (see text); length 25 mm.
11. tilt lever for pressure rolls spindle; U-shaped aluminium beam 10×10×1 mm; length 48 mm.
12. see 11).
13. angled support bracket for string wheel; U-shaped aluminium beam 15×15×2 mm; length 15 mm.
14. pen carriage; U-shaped aluminium beam 25×50×3 mm; length 60 mm.
15. pen positioning plate; aluminium; 8×50×2 mm.
16. pen carriage support; nylon; dia. 8 mm; length 23 mm.

**Miscellaneous parts:**

6 off slide bearings; nylon; Skiffy 08-6.
1 off bushing for platen; nylon; Skiffy 08-4 or 08-6.
2 off washer rings; internal dia. 3 mm; thickness 2 mm.
2 off rubber pressure rolls (e.g. cable grommet).
4 off fixing rings for dia. 6 mm spindle (e.g. Skiffy 11-1-6).
1 off string wheel.
3 off cylinder head screws M4×5.
2 off cylinder head screws M4×10 (for fixing part no. 3).
1 off cylinder head screw M4×20 with 3 nuts.
5 off M4×5 screws with countersunk head.
4 off cylinder head screws M3×40 (for fixing stepper motors).
2 off cylinder head screws M3×50 (for fixing part no. 15).
2 off cylinder head screws M3×10 (for fixing string).
2 off cylinder head screws M3×15 (for fixing spring brackets).
4 off headless adjustment screws M3×3 (for fixing part nos. 9 and 10).
6 off bolts M2.6×5 (for fixing pen lift magnets).
16 off hexagonal nuts M3.
2 off springs for pressure rolls spindle.
string; wound fishing line; 1100 mm*.
fine grade sandpaper (for securing on platen).

**Electromechanical parts:**

2 off stepper motors; 200 steps/rev.; dual-phase bipolar; 200 mA/phase (e.g. Berger as used in disk drives).
3 off pen lift electromagnets; 12 V; e.g. Binder Magnete Type 40031-09B00.

* Length in accordance with required size of plotter.
Distributor of Skiffy products in the UK is
Salterfix Fasteners • Salter Springs & Pressings Limited • Spring Road • Smethwick • Warley • West Midlands B66 1PF. Telephone: (021 553) 2929. Telex: 337877.

platen functions as a flat surface onto which the paper rests as the lines are drawn on it. An electromagnet to each pen arranges for this to be lifted from the paper when its colour is not required at a particular co-ordinate position on the sheet.

The drawings and photographs in this article, in combination with the mechanical parts list, should give sufficient details on the basic construction of the plotter, which is reverted to below.

4

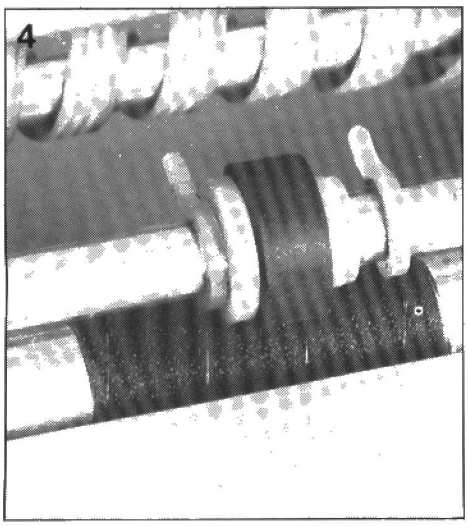


**Fig. 4. Close-up of the sandpaper grip on the platen, and the associated pressure roller plus clips on the movable axle. Also note how the 4-way flatcable to the carriage is wound on the rear rod to make a flexible connection with the plotter interface board.**

## Circuit description of the plotter interface board

The control circuit developed for the plotter is composed of a power supply, two stepper motor drivers, three buffers for energizing the pen lift solenoids, and an 8-bit digital interface to the Centronics standard.

The diagram of Fig. 5 shows that the circuit is based around integrated stepper motor drivers Type MC3479 from Motorola or SGS. Three inputs of each chip, clock, full/half step and direction, are driven direct by the computer via the input connector. The fourth input, OIC, enables selection between high or low impedance termination of the energized stator winding during half step operation. This selection is used for optimizing the dynamic response of the relevant motor. The resistor connected to the SET input of the driver IC determines the stator current. In the non-activated condition, $T_4$ and $T_5$ are turned off, so that the resistance between the SET inputs and ground is relatively high. This effectively keeps the stator current between 60 and 70 mA, ensuring a modest total dissipation of the motors and the driver ICs, whilst maintaining sufficient torque to keep pens and paper securely in position. A stepper motor is energized when the interface board receives a positive pulse transition on the relevant clock input (clc 1/2). The associated MMV is triggered, switches on the transistor ($T_4$ or $T_5$), and causes the stator current in the motor to rise to about 200 mA per phase. This rush-in current flows only briefly due to the inductance of the stator, and depends on the step rate. The driver IC, however, will counteract this reduction—within the practical limits of the supply voltage—to force a current flow of about 200 mA.

Opening switch $S_2$ disables the stepper motors to allow manual positioning of the carriage and/or the paper on the platen. In addition, opening $S_2$ resets the logic circuitry internal to the driver ICs to the initial state, as indicated by the illuminated LEDs. This state occurs at each fourth (or eighth) step, and the LEDs will light correspondingly.

The circuit for controlling the pen lift solenoids is relatively simple. Two-to-four decoder $IC_3$ selects one of the three pens. When both IC inputs are held logic high, or are not connected, all three pens are lifted. The electromagnets are actuated via darlington transistors and R-C networks. In these, the capacitor ensures a relatively high pull-in current, while the resistor limits the hold current to a level that is just high enough to keep the electromagnet actuated. Flyback diodes are fitted across the coils to suppress induced voltage peaks.

## Cutting, drilling, filing...

The mechanical parts are made or purchased as indicated in the Mechanical Parts List and the working sheet of

5

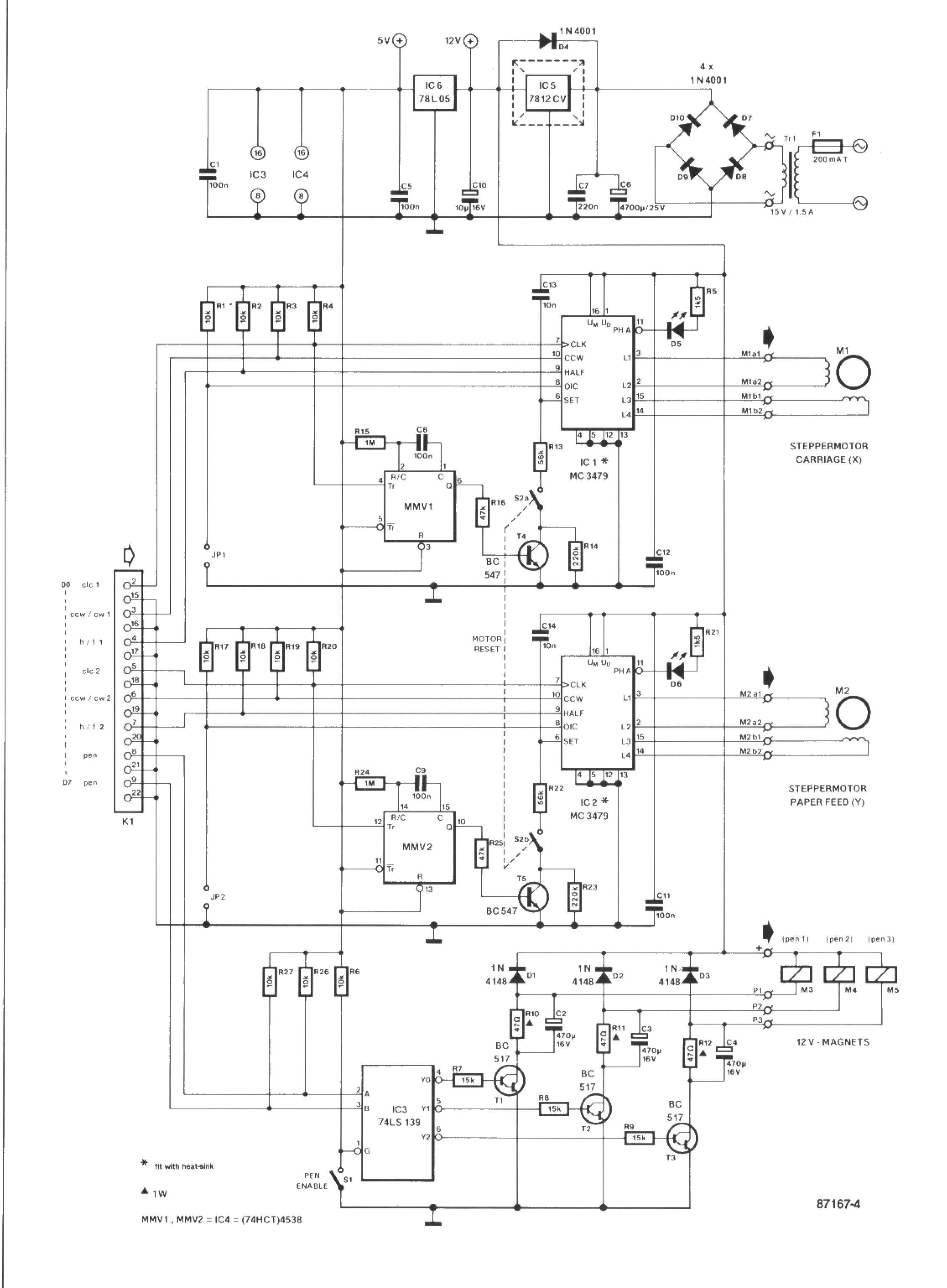



**Fig. 5. Circuit diagram of the plotter interface board.**

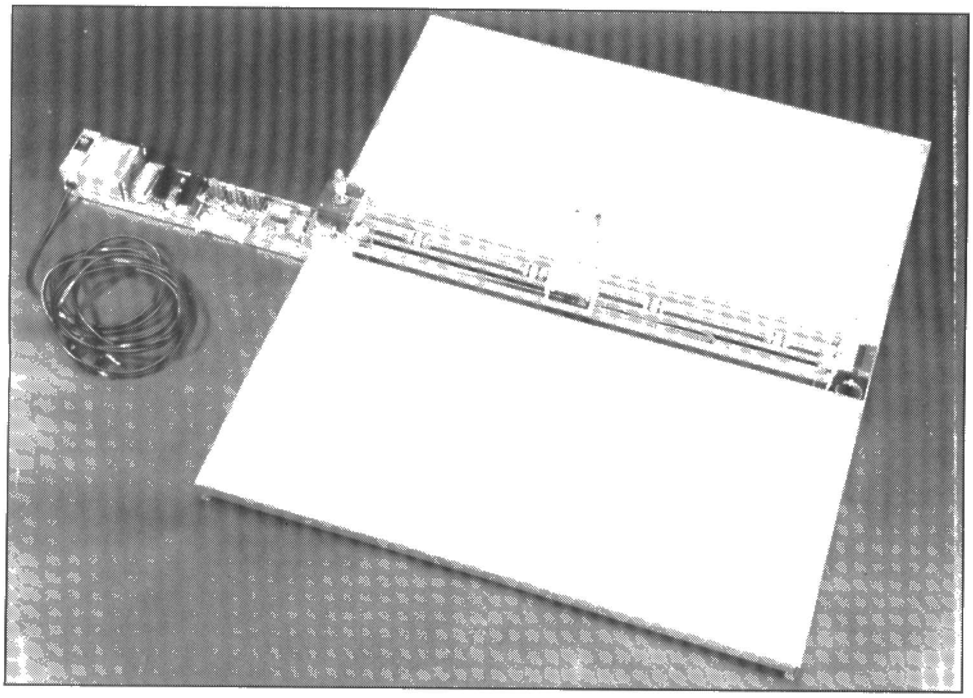
Fig. 3. Each of the 16 parts that must be made to size is shown separately and with the relevant dimensions. The side panels are cut from a 2 mm thick sheet of aluminium. They are preferably clamped together and drilled simultaneously to ensure accuracy. Use a centre punch for precise positioning of the drill, and lubricate this every now and then with methylated spirit to avoid burrs, and to clear aluminium shavings. A countersink drill should be used for sizing the upper hole in the right-hand support plate, which receives the head of the countersunk M4 screw bolt. The head must not protrude from the plate surface because this lies flat against the side of the stepper motor. Two additional 3 mm holes are drilled in the left-hand plate for securing the Y motor. Rods 4, 5, 6 and 7 are cut to equal size as required for the width of the plotter. The centre of both ends of each rod is pre-drilled with a 3.3 mm drill before tapping an M4 thread. Be sure to drill exactly in the centre of the axle: a lathe is, of course, ideal for this operation, but not strictly required for acceptable accuracy.

There is, however, no way to go round the use of a lathe for reducing the platen diameter where the sandpaper is to be secured. Unfortunately, a lathe is neither easy to control nor a commonly available tool. It is, therefore, recommended to have the platen turned to the required local thickness in a mechanic's workshop. Also remember that drilling an off-centred hole in the platen where it is secured to the motor shaft will wreak havoc by causing friction in the nylon bushing at the other end of the rod, and, more seriously, irregular paper motion. The free end of the platen is turned to a diameter of 4.2 mm over 4 mm with the aid of a lathe to enable it to revolve in the nylon bushing. The shaft fitted onto the spindle of the second stepper motor is made by cutting off a short length of the platen tubing. The remaining components, 11...16 incl., are relatively simple to make and require no further discussion.

## Construction of the interface

The plotter interface board is a single-sided type which is available ready-made through the Readers Services. Construction is straight-forward by reference to the parts list and the component overlay of Fig. 8. Resistors $R_{10}$, $R_{11}$ and $R_{12}$ are 1 W types mounted slightly off the board surface to aid in their cooling. Drivers $IC_1$ and $IC_2$ require fitting with a DIL clip-on or glue-on heat-sink—see Fig. 6. It is recommended to solder the ICs direct onto the board, so that the ground area can aid in convecting dissipated heat. $IC_4$ is a type from the 4000 series, and has the disadvantage that its input is not TTL-compatible. In practice, however, pull-up resistors $R_4$ and $R_{20}$ ensure correct operation of the interface in conjunction with virtually any Centronics port. None the less, when incompatibility problems are suspected (the motors then appear not to start properly), $IC_4$ may be replaced by an equivalent of the HCT type. Jumpers $JP_1$ and $JP_2$ are not fitted.

As already stated, the input header on the board is wired in a manner that facilitates connection to a Centronics port via a length of flat ribbon cable. Handshaking is not used in this arrangement.



Completed prototype of the plotter. This is a relatively wide version (508 mm) mounted on a flat aluminium base plate for improved paper stability (A2 sideways; A3 lengthwise). It has four paper grips to ensure that lines of minimum thickness are drawn reliably and accurately.

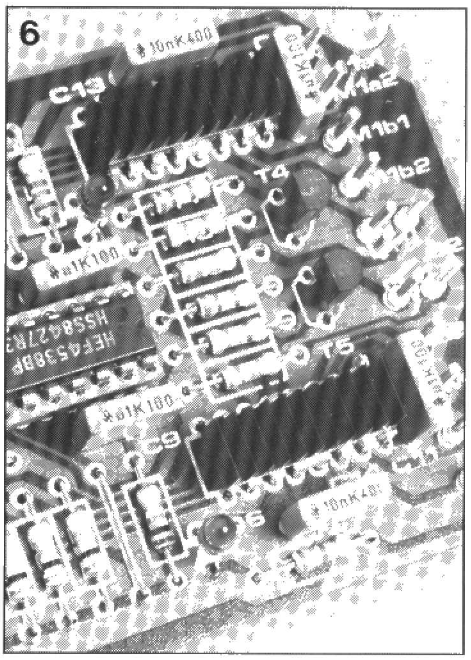


**Fig. 6. The stepper motor driver ICs on the interface board require cooling by heat-sinks of a type that can be glued on top of a DIL package.**

### A note on stepper motors

The stepper motors used for building prototypes of the plotter were Berger types salvaged from discarded disk drives. Similar types may be used if these have the following specifications:

- 200 or 100 steps/rev. (≙1.8° or 3.6° per step);
- current consumption: approx. 200 mA/phase;
- two bipolar phases;
- resistance for each phase (stator): 30...40 Ω.

Unfortunately, many motors may not meet with the above specification in respect of the stator resistance. These types exhibit much lower values (e.g. 1.33 Ω), and require driving from current sources. According to the manufacturers, the driver ICs Type MC3479 on the plotter interface board have current source output stages, but in practice these may be damaged when connected direct to a very low stator resistance. It is, therefore, good practice to check the stator resistance of the motors envisaged for use in the plotter. If necessary, add a suitably dimensioned series resistor to ensure that each stator output on the driver ICs is loaded with 30...40 Ω. Example: use a 33 Ω; 4 W resistor when the stator alone has a resistance of 1.33 Ω.

7

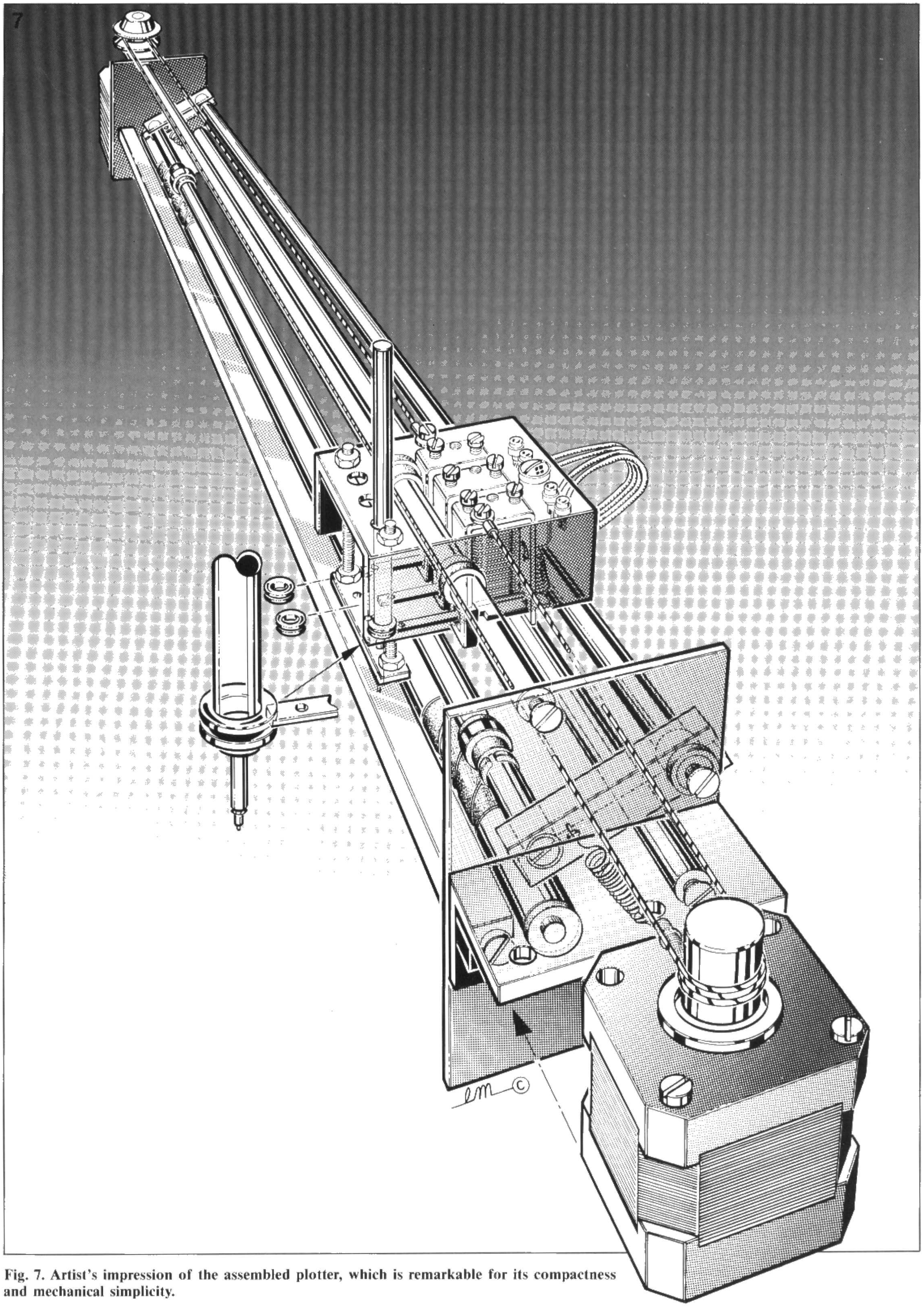


Fig. 7. Artist's impression of the assembled plotter, which is remarkable for its compactness and mechanical simplicity.

8

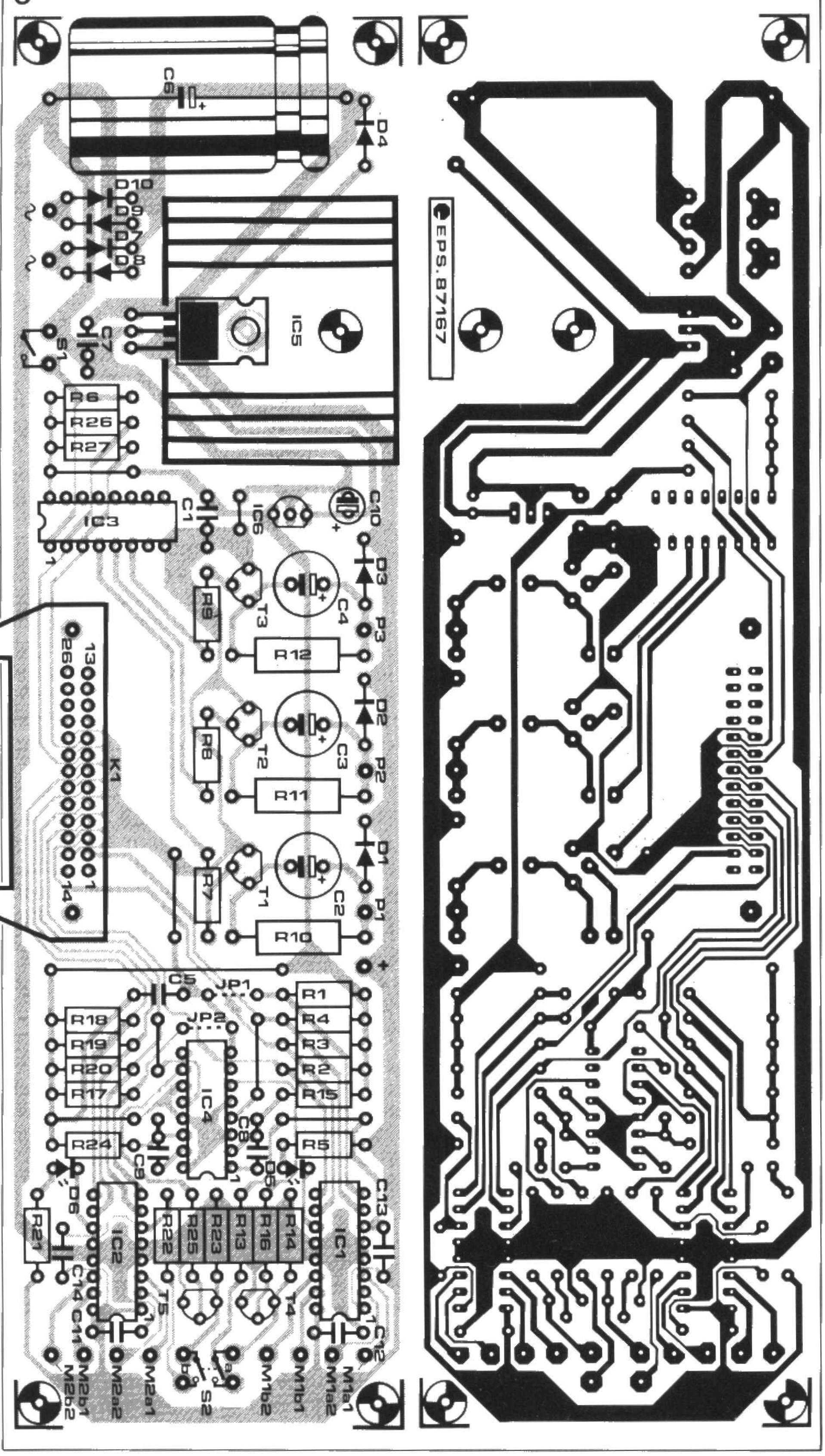



Fig. 8. Track layout and component mounting plan for the plotter interface PCB.

**Parts list**

STEPPER MOTOR INTERFACE BOARD

Resistors (±5%):

R1 . . . R4 incl.;R6;R17 . . . R20 incl.;R26;R27 = 10K
R5;R21 = 1K5
R7;R8;R9 = 15K
R10;R11;R12 = 47R; 1 W
R13;R22 = 56K
R14;R23 = 220K
R15;R24 = 1M0
R16;R25 = 47K

Capacitors:

C1;C5;C8;C9;C11;C12 = 100n
C2;C3;C4 = 470μ; 16 V; radial
C6 = 4700μ; 25 V
C7 = 220n
C10 = 10μ; 16 V
C13;C14 = 10n

Semiconductors:

D1;D2;D3 = 1N4148
D4;D7 . . . D10 incl. = 1N4001
D5;D6 = red LED
T1;T2;T3 = BC517
T4;T5 = BC547
IC1;IC2 = MC3479 (Motorola; SGS) (C-I Electronics)
IC3 = 74LS139
IC4 = 4538 or 74HCT4538
IC5 = 7812
IC6 = 78L05

Miscellaneous:

S1 = miniature SPST switch.
S2 = miniature DPDT switch.
K1 = 26-way right-angled IDC header for PCB edge mounting.
Mains transformer; 15 V/1.5 A secondary.
Euro-style mains entrance socket with integrated fuseholder and switch.
Fuse; 200 mA delayed action.
Heat-sink for IC5.
DIL heat-sinks for IC1;IC2.

The completed board is secured onto the mains transformer and the plotter. The two switches are connected as external controls, together with the mains switch. Do not forget the mains fuse, which should be connected ahead of a suitably rated DPDT mains switch. A Euro-style mains entrance socket with integral switch and fuseholder is, of course, the safest and easiest alternative in this respect. Indicators D5 and D6 need not be visible when the interface is fitted in an enclosure, although this may prove useful during testing and setting up.

---

Part 2 of this article will deal with general condiderations on control software for the plotter.

**Note:** The plotter and associated interface board are available as a kit from the Dutch mail-order company Meek-it Elektronika (see their advertisement in this issue of *Elektor Electronics*). Readers should note that the mechanical parts in the kit may deviate slightly from the specifications stated in this article.

# ARTIFICIAL INTELLIGENCE

by M. Seymour, BSc, University of St. Andrews

**Man is intelligent, but his intelligence is often thwarted (or worse) by his environment. That realization has given rise to a dream: that one day it may be possible to build a machine that can think, that is, need not be programmed to perform its functions.**

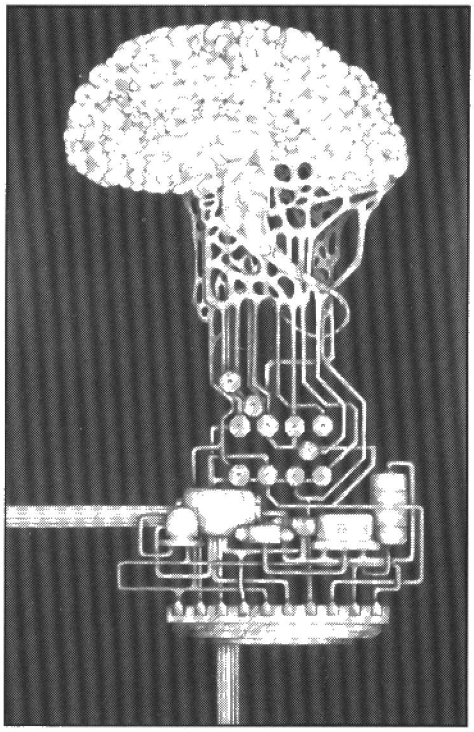
Machine intelligence was first thought of by Charles Babbage (1792-1871). This century, Alan Mathison Turing (1912-1954) has achieved immortality through the Turing Machine, which purports to show that machines are mathematical objects, and his proof of the theorem that the set of mathematical tasks that is computable is exactly the same as the set that can be executed by the machine. He also formulated a theory about what questions could in principle be answered by an intelligent machine.

Artificial intelligence grew out of the work on digital computers during the Second World War and was officially recognized as a branch of computing science in 1956. Since those early days, artificial intelligence has given rise to a number of myths, particularly, but not only, in the popular press. However, claims of computers achieving this and that, without human intervention, always prove, on close examination, to be mere illusions of intelligence. These illusions are created by the fact that computers work so extremely fast.

Fortunately, such illusions are now recognized as such and the true science of Artificial Intelligence is taking shape. The aim of this science is not to create machines that are as intelligent as humans (it is doubtful whether this will ever be possible), but rather to create machines that are ever more capable of meeting human needs. Such machines need to be able to learn about their users and to do that, they will have to see, hear, and understand. Moreover, they must not make demands on their users as far as programming is concerned. Ideally, this would mean that the machine responds to normal spoken language. Only limited progress has been made in that direction.

The theory of artificial intelligence says that if you analyse the world in symbols and put the right rules (=program) in the machine it will have a mind and understand the world as we do. In other words, it will be a thinking machine.

Some researchers say that any computer can simulate any other computer, be it serial, parallel, digital, or analogue. Assuming the human brain to be a computer, they assert that it must be possible to find the program that makes the



human computer function. Once found, this program can then be used to run any other computer, which will consequently be intelligent. But is there such a program and will it ever be found?

Other researchers feel that because of the world we live in, we suffer from the illusion that every substantive problem should have a technological or scientific solution. Because such answers are not forthcoming, we believe that a better technology or a more advanced science is required to solve the problems. It is easy to think of artificial intelligence in this context.

These researchers do not believe that it is simply a matter of calling our brain a computer and saying that it has been 'programmed'. Human intelligence is not just the ability to think logically: there is memory, experience, background, emotion, and so on. It is, perhaps, experience that creates the greatest distinction between artificial and natural intelligence. The relationship between human mental events and experience of the real world is called intentionality. It is these researchers' contention that no existing machine or program has intentionality. Artificial intelligence is, at present, proceeding along the lines laid down by these researchers, that is, with the aim of constructing a machine that is most capable of meeting human needs.

The most publicly visible applications so far are so-called Expert Systems. These are programs that are used to give advice on medical diagnosis and prescription, genetic engineering, chemical analysis, and geological prospecting for minerals and oils. Although most of these programs are very limited in what they can do, some give more reliable advice than all but the very best human experts.

Computers developed for Artificial Intelligence are called fifth generation computers. The first four generations are defined in hardware terms: machines based on valves; transistors; integrated circuits, and VLSI. The fifth generation is defined in terms of parallel operating hardware and artificial intelligence.

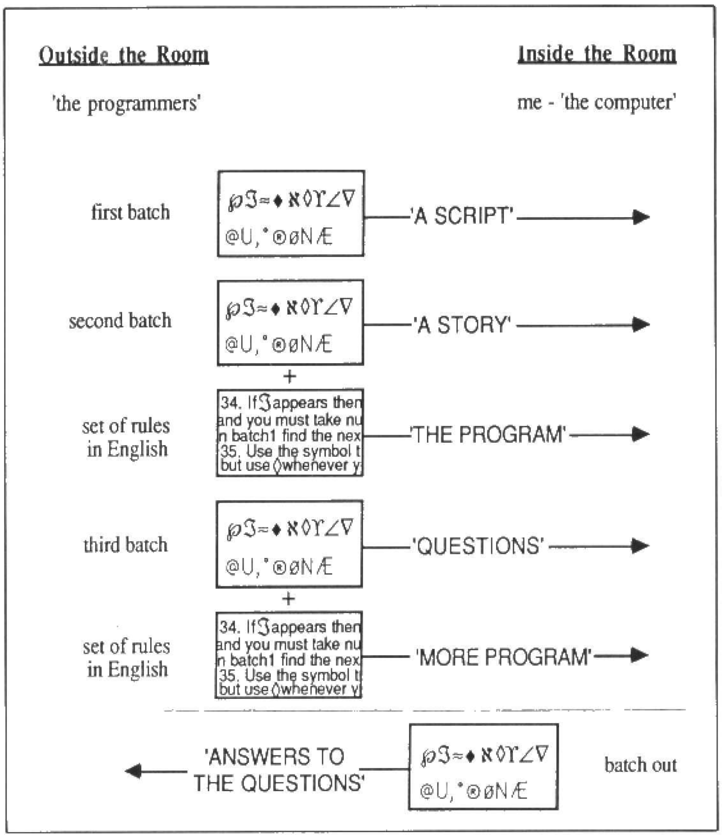
Although the governments of all western nations, and, no doubt, that of the USSR also, are pouring money into the research and development of fifth generation computers, workers, in the field have found that the difficulties involved have been grossly underestimated. One of the important facts that has emerged is that human common sense plays a far greater role in our daily lives than hitherto generally imagined.

Common sense enables people to cope with the fact that a statement assumed to be true at one time can later be found to be false. Computers, which depend on traditional logic, wherein truths are proved once and for all, can not come to grips with this — at least not yet.

Everyday abilities like talking, seeing, or sensing friendliness from a facial expression, do not normally need conscious effort. Nor can we say how we do them. As long ago as the 5th and 4th centuries BC, Socrates and Plato concluded that although early on in life we learn the rules (i.e. are programmed) for these functions, they are quickly forgotten and retained only in our subconscious mind once we grow up. None the less, these functions are far from simple. Indeed, their complexity — and subtlety — was

## The Chinese Room

John Searle, Professor of Philosophy at the University of California, defines two forms of artificial intelligence research. *Weak AI* merely says that the principal value of the computer is that it gives us a powerful tool in the study of the mind. Advocates of *Strong AI*, however, maintain that the digital computer is not merely a tool, but rather, if correctly programmed, a mind that can literally be said to *understand* and to have other cognitive states. Searle believes that the 'equation' MIND/BRAIN = PROGRAM/HARDWARE is invalid.
Imagine yourself (it is assumed you are not a Chinese speaker) inside a closed room. Your only contact with the outside world is through a small hatch. In through the hatch comes a large batch of Chinese symbols. Some time later, another batch arrives, along with a set of rules in English (which, it is assumed, you *do* understand) correlating the first set with the second. You carry out the instructions, no doubt wondering what you are doing, and another batch is submitted, with more rules in English. These rules tell you to check this third set of symbols against the first two, and to send back out certain symbols from the first large batch as a result of this checking process.
After a time, you get so proficient at this process that it seems as though you are fluent in Chinese. The third lot of symbols, you see, are questions and those you send out are answers to these questions. The point here is that, although you understand the English rules, you have no idea what the Chinese symbols mean.
Searle asserts that the Chinese Room is analogous to the way the digital computer works. Alan Turing showed that any computer can be reduced to a Turing machine, which merely manipulates symbols according to a set of rules. A computer running a program does precisely, and only, that. It can not, therefore, be said to understand what it is doing.
In his original paper, Searle gives six replies to his argument and




**Schematic diagram of the main features of Searle's Chinese Room argument. The symbols used are, of course, not Chinese, but hopefully convey the point that taken together they mean nothing to you.**

counters them. In the journal in which the paper appeared, twenty-seven further replies were given. We shall only deal here with the original six, but it may be noted that although the paper was published in 1984 the argument is still hotly debated today.
**The Systems Reply.** It is wrong to think of *me* understanding Chinese: the whole room is the understanding agent.
This seems at first glance somewhat incredible in terms of the Chinese Room, but it is motivated by the feeling that my brain understands nothing, but that *I* do.
Searle says that all one needs to do is "internalize" the rules, i.e., memorize them. But, one still does not understand Chinese then; merely following a set of rules one has memorized is not to understand the meaning of what they are about.

**The Robot Reply.** Maybe the computer on its own does not understand, but put in the cranial cavity of a robot, give the robot manipulating arms, sensors, and a television eye, and it will understand as we do.
No, says Searle, for just imagine yourself and the room inside the robot's head. I can see the symbols through the camera, I can manipulate them with my mechanical arms, but, of course, I still don't understand.
**The Brain Simulator Reply.** If you get the computer to actually simulate all the neuron firings at the synapses of the brain (in particular, of the brain of a native Chinese speaker), how can the computer fail to understand Chinese — it seems as if we would have to deny that the Chinese speaker understood, if we thought otherwise.

Searle thinks that the computer is simulating only *part* of the brain: the neural structure, but that is not enough. You could make a brain out of beer cans in a similar way and it would not think. In the context of the Chinese Room, connect the input and the output of the room via a system of water pipes and valves that are structured in the same way as the neurocortex. Yet again, I do not understand Chinese.
**The Combination Reply.** Combine the three previous responses so that we have a robot with a computer in its head, programmed with all the synapses, etc. of the human brain, and think of the whole thing as a unified system. We would have to ascribe intentionality* to the system.
Searle thinks it is not sufficient just to have something that looks and behaves like us.
**The Other Minds' Reply.** How do we know if *anyone* else understands Chinese? Well, by their behaviour.
According to Searle, one must presuppose the reality and knowability of the mental in the same way as we presume the reality and knowability of the physical world when we do physics. Obviously, this is another contentious issue in the light of some interpretations of quantum theory, for instance, but Searle gives it short thrift.
**The Many Mansions Reply.** Although we are working with analogue and digital computers *now*, in future we could well build devices that have the causal power of the brain, of which intentionality is a product.
Searle agrees wholeheartedly, but it is no argument here, because such a machine would not fall within what we now define as AI, which, in its strong form, is the only thing with which he is concerned.

* Intentionality, according to Searle, is that feature of certain mental states by which they are directed at or about objects and states of affairs in the world. Thus, beliefs, desires, and intentions (as we commonly use that word) are intentional states; undirected forms of anxiety, depressions, and so on, are not!

not appreciated until researchers tried to model them on computers.
Although the activities that involve our common sense have so far proved an insurmountable obstacle to artificial intelligence, there are as already stated expert systems that can give advice on a number of problems faced by genetic engineers, physiologists, geologists, and mathematicians. The widespread ignorance of this, perhaps not so surprising, paradox may present a danger because most people lack a reliable sense of which questions AI systems can at present be expected to cope with.
Current development work indicates that one of the important aspects to be tackled is to give fifth generation computers a much better grasp of natural language. Most people are not prepared to learn a special pogramming language. Moreover, the machines would not be able to learn about their users through normal conversations. However, the difficulties are great and at present it is expected that future expert systems will have a command of the natural language only within the subject for which it was designed.
A technology that was originally developed in the 1950s, but was abandoned after ten years, has recently been revived. It is called neural computing and could be of inestimable value in the creation of true artificial intelligence. Neural computers attempt to copy the human brain and are quite unlike conventional computers, because they are not programmed, but can learn by

example.
The brain is a complex network of interlinking neurons. It is the interlinking that is the key to solving problems quickly, but it is a problem in computer engineering: to create a 1 million-node network with 1 billion 'hardwired' interconnects would require 92 $m^2$ of silicon. The Oregon Graduate Center's Computer Science and Engineering Department is planning to build a neural computer with 10,000 nodes linked by five million interconnects. However, by using frequency-based encoding for the interconnects instead of hardwiring only 0.8 $m^2$ silicon is needed.
Neural computers may help in solving problems that still defeat conventional computers in spite of the enormous increase in processing power made possible by VLSI technology. These problems include pattern processing tasks, such as speech recognition, and the creation of content addressable memories.

**References:**
1. Minds, brains, and programs. *Behavioural and Brain Sciences* 1980, 2. By Prof. J. Searle.
2. *Principles of Artificial Intelligence.* By N.J. Nilsson (1980).
3. *Artificial Intelligence and Natural Man.* By Prof. Margaret A. Boden (1977).
4. *Expert Systems in the Microelectronic Age.* By Prof. D. Michie (1979).
5. *Intentionality: Essays in the Philosophy of Mind.* By Prof. J. Searle (1984).
6. *Alan Turing, The Enigma of Intelligence.* By Andrew Hodges (1983).
7. *What Computers Can't Do (A Critique of Artificial Reason).* By Prof. H.J. Dreyfuss (1972).
8. *Expert Systems Technology: A Guide.* By L. Johnson and E.T. Keravnou (1985).
9. *A Perpective on Intelligent Systems.* By L.J. Kohout (1985).
10. The Future for Artificial Intelligence. *Elektor Electronics*, November 1985. By Prof. Margaret A. Boden.
11. How Does The Human Computer Work? By Dr. Kevan Martin. *Elektor Electronics*, May 1987.
12. Is the Chinese Room the Real Thing? *Philosophy*, 62, 389-393. By D. Anderson (1987).
13. Minds and Brains without Programs, by J. Searle in *Mindwaves* (1987) eds C. Blakemore and S. Greenfield.

# SIMULATING SIGHT IN ROBOTS

by Arthur Fryatt, CEng, MIProdE

Although industrial robots have been in widespread use for well over ten years, their inability to respond intelligently to unexpected or rapidly changing situations has limited their usefulness to tasks in highly ordered environments. The problem is the robot's lack of awareness of what is happening around it.
Attempts to solve this problem have led to the development of sensory systems that in some measure emulate human vision, touch and hearing. Most research has concentrated on the design of computerized vision systems which act as the robot's eyes and brain to provide a basic form of artificial intelligence.
The major parameters of robot vision systems are recognition, location and inspection. With this information, a robot knows what components are present in its workspace, where they are positioned, and the extent to which they are dimensionally or structurally correct.
Although it can be seen that the development of vision systems is extending robot technology into inspection and assembly, some of the most promising commercial developments have occurred in paint spraying, welding and colour quality control of items such as fruit and vegetables. Co-operation between British research institutions, universities and manufacturers is increasing the range of commercial applications.

## Practical Research

One of the leading research institutions in the United Kingdom for the development of vision systems is the National Engineering Laboratory (NEL)(1) which has designed a considerable amount of software for manipulating and interpreting images. For scenes that display high contrast between components and their backgrounds, a simple thresholding operation will convert the grey scale input array into a binary image in which each pixel has the value 0 (background) or 1 (component).
Binary images can be efficiently stored in a computer memory and their simple format enables fast analysis to be carried out to determine dimensional and topological measurements. These values, along with other invariant features, can be used to build a simple component recognition and location strategy that will operate effectively on uncluttered scenes.
Reliance on high contrast effectively precludes the use of binary processing techniques in most engineering applications, which are typified by visually "noisy" conditions such as poor light levels, low contrast, or components lying jumbled together in bins partially obscured by other workpieces.
In such situations an alternative approach to recognition is based on matching local features (boundary segments, corners, holes and so on) rather than on matching global feature values (area or perimeter length, for example). The NEL has recently developed advanced techniques for the matching of local features involving the latest computer-on-a-chip device.
A practical example of robot vision work at the NEL is a recent project undertaken for the National Nuclear Corporation involving the development of a system for automatically locating fuel pins in a nuclear fuel assembly.
Accurate information on pin position is communicated to a robot which grasps and removes each one in turn. The NEL system is ten times faster than manual dismantling.

## University collaboration

A vision sensing system provides colour quality control for grading fruit and vegetables in the Autoselector, a joint development involving the Essex Electronics Centre(2), a department of the University of Essex and Loctronic Graders(3). Their collaboration initially led to the introduction of the Autoselector A, which employed a monochrome television imaging technique to detect differences in the grey scale.
Subsequently, with the introduction of the Autoselector C, a very significant advance has been achieved with colour imaging which enables up to 4096 colours and shades to be identified in areas as small as 3 mm diameter at very high speed.
Since the entire area of the product needs to be scanned, Loctronic Graders has developed the Thrudeck which presents constantly revolving products such as tomatoes, onions, kiwi or citrus fruits at speeds up to 2500 per minute to the camera. Even though the products are of irregular shape, the system can track, size and count each one as it follows a meandering path down the deck.
Another interesting technical achievement is the way in which the three-dimensional aspect of colour television is handled. Since a colour camera has

three channels — red, green and blue — the permutations possible could be handled only by a very large computer. In conjunction with the Electronics Systems Engineering Department of Essex University, the Electronics Centre developed a method simplifying this task so that it can be handled by hardware controlled by a Motorola 68008 microprocessor.
By selecting the region of colour hue carefully — for example green and brown for potatoes, or red and green for tomatoes — and examining tone saturation in the chosen colour sector, dimensions are reduced from three to two, which can be handled relatively easily.

## Sighted robot welding

Founded at the beginning of 1984 with the help of an Oxford University research team, Meta Machines[4] is now accepted throughout the world as a leading commercial organization specializing in sensors for robot control. Its MetaTorch adaptive vision guidance and control for arc welding is designed to ensure that a robotic welding system achieves consistently high quality output despite components fit-up variations and inaccuracies. The aims are minimum downtime for reprogramming in response to component batch changes, and maximum flexibility to adapt to future changes through the fixing of simple and inexpensive parts.
The company's two most recent developments are the MetaTorch 200, a compact vision sensor mounted co-axially around an MIG or TIG welding torch and the MetaTorch 500, for higher current applications, on which the vision sensor is mounted external to the welding torch. The Metatorch system can recognize complex joint types, guiding the robot to locate, track and weld the seam in a single pass operation.
The vision processing electronics and powerful vision processor enable the system to analyse the position of the joint and communicate this information to the robot controller at a rate in excess of 10 Hz. As a result of its single pass operation and fast vision analysis, the system has no significant effect on the robot cycle time.
Used in production environments, the MetaTorch requires no optical adjustment or alignment and is quickly interchangeable. By combining a solid state laser light source and camera in a single unit, it is capable of withstanding harsh operating conditions.

## Precise spraying

By combining closed circuit television with automatic paint spraying equipment, Lektrodesigns[5] has developed the Videospray system, which can assess separate paint stroke requirements. It controls spray patterns individually so that irregular shapes loaded on a conveyor at random will be painted automatically with a minimum of paint.
Mounted together on a single stand, the Videospray's closed circuit television (CCTV) camera with built-in monitor and electronic module are easily installed adjacent to existing spray equipment.
Any reciprocating gun can be controlled and one unit can handle up to four spray guns. To establish the relative positions of the spray gun and the item to be painted, the camera is directed so that the reflector on the spray gun, and the workpiece as it enters the spray booth, are in view. From this relationship, timing instructions are generated and stored in the logic bank to control the spray stroke, ensuring paint economy.
It is possible to achieve an accuracy of paint spray to 12.7 mm with the electronic and mechanical time lag provided by the system, even to the extent of compensating for angular workpieces where the gun needs to be rotated through an arc. The complete Videospray installation occupies only 0.8 $m^2$ of floor space and on average rises to a height of 2 m.
The company's latest development is the Videospray II, a shape recognition system again comprising a CCTV camera linked to a microprocessor, which in turn can be connected to a painting robot to call up the appropriate part painting program. A particular feature is the method of lighting the part moving on a conveyor to give a strong silhouette for the camera to view. A microprocessor digitizes the outline shape and compares it with a pre-stored library of shapes to determine the part number.
Outline recognition software routines have been incorporated to determine the attitude of parts on the conveyor, for example, higher, lower, tilted, retarded or advanced, compared with their mean positional attitude.

**References:**

1. National Engineering Laboratory, East Kilbride, Scotland G75 0QU.
2. Essex Electronics Centre, Wivenhoe Park, Colchester CO4 3SQ.
3. Loctronic Graders Ltd, Eves Corner, Danbury, Essex CM3 4AH.
4. Meta Machines Ltd, 9 Blacklands Way, Abingdon Industrial Park, Abingdon, Oxfordshire OX14 1DY.
5. Lektrodesigns Ltd, c/o Market Options Ltd, 75 Middle Gordon Road, Camberley, Surrey GU15 2JA.

# COMPUTER NEWS

## Multi-ROM for Quantum Leap

Micro Control Systems (MCS) have recently introduced Multi-Rom, a plug-in memory cartridge for the Sinclair Quantum Leap. The product is ideal for developing ROM-based software, as code may be downloaded quickly for testing and debugging without programming EPROMs.

The so-called *Black box* is well known in the context of modern aviation, but Quantum Leap owners will immediately think of the plug-in ROM that can be fitted in a slot at the rear of the computer. The best known application is the famous Toolkit 2, which contains updates and corrections on QDOS and SuperBasic. Other programs familiar to most QL users are ICE, CPM-ulator and a number of programming languages (Metacomco C and Prospero) can also reside in ROM. The QL has only one ROM extension slot, however, and has to be switched off before cartidges can be exchanged. This procedure has the disadvantage of being cumbersome and causing contact wear on the slot connector and the cartridge PCB. Relocatable software offers a way out of this problem. Programs written in relocatable code are copied from ROM to RAM and can, in principle, be run simultaneously.
The Multi-ROM unit provides software and hardware that makes it possible to simulate 16K ROM in memory area \$0C000...0FFFF. This is achieved by (quasi-) programming of a (quasi-) EPROM by means of programming software that is, itself, ROM-resident, and copied into RAM (common heap) following a cold or warm re-boot. Two 8 Kbyte static RAMs in Multi-ROM then take the position of the switched off ROM in the memory map. The hardware for switching from RAM to EPROM and vice versa is a clever design. Switching takes place after reading locations \$0BFBx. These addresses are at the top of the QL system ROM, and are never read by QDOS:

- Read 0BFB0 (49072): EPROM
- Read 0BFBC (49084): write protected RAM
- Read 0BFBE (49086): r/w RAM

Multi-ROM uses the R/W signal from the QL to control internal hardware. Since the R/W signal is not present on the QL RM slot, it is connected to Multi-

ROM by means of a separate wire supplied with the unit.

As to software, ROM-based programs must first be copied to floppy (flp) or microdrive (mdv). This creates ROM images, and can be done with instruction

SBYTES
flp1[mdv1]_name,49152,16384.

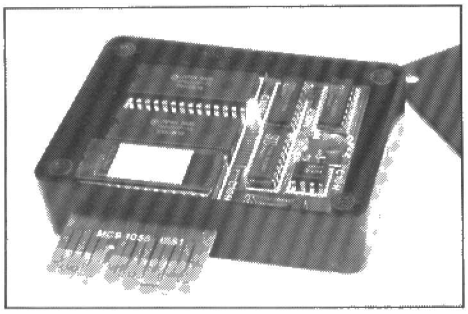
The next instruction,

flp1[mdv1]_name

loads one of the ROM images in the RAM on board Multi-ROM. This RAM is write-protected when loading is completed. The new quasi-ROM can be taken up in the system memory recognized by QDOS by arranging for a warm start (= cold start without RAM testing). If the software is already present in RAM, a jump follows to the next program line, or to SuperBasic (flashing cursor in window #0). This makes it possible to use LOAD_ROM as part of the bootstrap batch file without creating an infinite loop. BASIC extensions can be used in the boot file immediately after LOAD_ROM. The usage includes that by JH and AH system ROMs.

Command RUN_ROM can be used for programs that can run in RAM also (e.g. the Tebby Toolkit). The program is started on the basis of the ROM header when its ROM image has been copied in the QL-resident RAM (that is, not the extension RAM).

Command DEVLIST gives an overview of all system devices recognized by MULTI-ROM. New devices can be addded with the aid of instruction ADD_NAME. PRINT DEFDEV$ shows the current default. EXIST [file] or [device] returns 1 or 0 depending on whether a device is in use.



Finally, a short copy program is given below to illustrate the use of the MULTI-ROM extension in conjunction with SuperBasic:

```
100 DEFine PROCedure RAM_RW
110 PRINT#0, peek (49086)
120 END DEFine
130 DEFine PROCedure RAM_WP
140 PRINT#0, peek (49084)
150 END DEFine
160 DEFine PROCedure EPROM
170 PRINT#0, peek (49072)
180 END DEFine
```

In conclusion, Multi-ROM is an extremely useful extension for the Quantum Leap computer, and well worth its cost. The unit is ideal for all those programmers with a need for a versatile tool that allows straight-forward and time-efficient developing of ROM-based software. Multi-ROM is a neatly constructed unit measuring just 90×60×20 mm. Installation and available commands are covered in the manual supplied with the unit. Multi-ROM is backed by a two-year warranty, and is available at £49 plus VAT from

Micro Control Systems • Electron House • Bridge Street • Sandiacre • Nottinghamshire NG10 5BA. Telephone: (0602) 391204.

## Computer claims unfair dismissal

A computer, sacked for failing to work hard enough, claims it was not given sufficient work to do.

The employer states that the computer was assigned the tasks of producing letters and mailshots, general and word processing, accounts, spreadsheet calculations, and monitoring databases about consumers, products, and sales. Despite this, counsel for the company management said that the computer was idle for significant periods during the day, and virtually all the night. Furthermore, while unsupervised at the weekends, the computer did no work at all.

The computer responded by alleging that it had been expressly excluded from lots of jobs.

It cited specific examples of communications with databases world-wide, production of newsletters and advertising material, drawing and presentation of information, maintenance of diaries, planners, and notebooks. These could have kept it working flat out, 24 hours a day, it claimed. The computer then accused the management of failing to be aware of all the types of jobs that computers can perform.

After a short adjournment, the judge ordered the re-instatement of the computer, and committed the company management to a course of enlightenment and education.

The computer was awarded costs.

To avoid litigation, get a free leaflet to show how computers can work long and effectively for the benefit of their employers from: **Mektronik Consultants • Linden House • 116 Rectory Lane • Prestwich • MANCHESTER M25 5DB • Telephone 061-798 0803.**

## General Purpose Controller

The GPC02 card is a powerful control and governing module in the standard Europe 100×160 mm size. It operates on the powerful ABACO (R) 16-bit bus, which is compatible with the SC84 bus. The card is based on the Intel 51 family of CPUs (8031, 8052, 8751, etc.), which come with or without an internal EPROM.

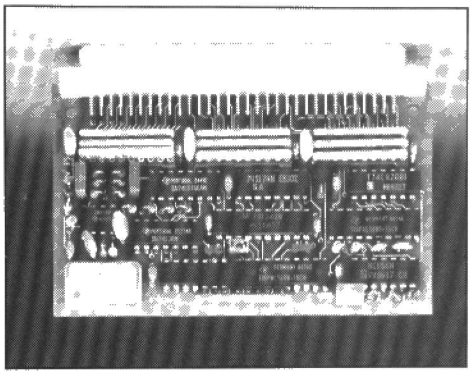
The development and set-up of programs for this card can start with the single GPC02, since this is already provided with the minimum outfit, including a built-in EPROM programmer.

The design of the GPC02 card makes it suitable for the control of medium-complex units. For more complex applications, its performance may be extended by the addition of suitable cards to the ABACO bus.

Details from **Grifo di Damino • 40016 San Giorgio di Piano • BOLOGNO • Italy • Via Dante 1 • Telephone +39 51 89 20 52**

## System controller saves board space

Fitting a system controller module onto the back of a P1 connector frees a board position in VMEbus racks. Compcontrol's CC-101 general purpose system controller is packed onto a module measuring just 100×60 mm, and thus suits single- and double-height VMEbus racks. The module works in 16- and 32-bit VMEbus systems, and is the first to make all board positions in a VMEbus rack available for application-specific boards—particularly valuable in systems made up of racks that use only five slots.



The board saves even more space in VMEbus systems if active or passive VMEbus termination networks are incorporated. It generates the 16 MHz VMEbus system clock, and the 2.9 MHz VMEbus serial clock. All bus time-out, system power-on, and reset circuits are included, and there is an input for an external reset switch. The board provides a four-level priority or rouind-robin bus arbiter, and there is an arbitration time-out function.

Details from **Compcontrol BV • Stratumsedijk 31 • P.O. Box 193 • 5600 AD Eindhoven • The Netherlands • Telephone +31 40 12 49 55.**

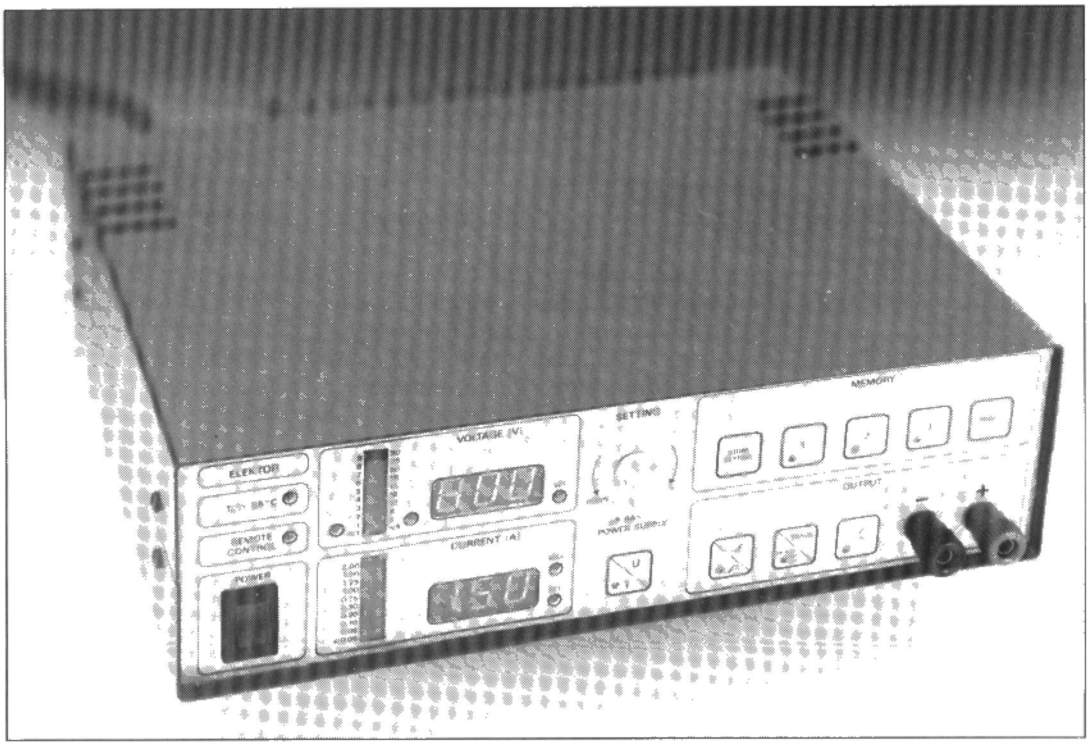
# LETTERS

Sir—I read with dismay C.H. Freeman's article ''Videotex: a promise unfulfilled?'' in your February issue.
Mr Freeman's inability to distinguish between videotex and Prestel is his first, but by no means most serious, error. Such an inability would have been no less remonstrable back in 1985 when the article appears to have been written.
But even in 1985, any article purporting to analyse Prestel's ''failure in the residential sector'' without a single mention of Micronet must be considered at best poorly researched.
In 1985, Micronet, the Prestel-based microcomputing service, had over 17,000 subscribers (out of a Prestel total of 50,000) who accounted for half of Prestel's mailbox traffic. Micronet's database generated over one third of all frame accesses. Telesoftware (automatic downloading of computer programs), Chatline (real-time national public teleconferencing), Starnet (multi-user strategy game of war and commerce) and Gallery (national publication by subscribers of their very own electronic databases, daily update) were already very popular on Micronet. But all these escaped the notice of Mr Freeman, who contents himself with the second hand conclusion that games and entertainments ''died a natural death''.
Since 1985 Micronet has increased its subscriber base and doubled its turnover whilst its parent company, Telemap Group Ltd, has expanded into wider consumer videotex services both domestic and international.
So much for the ''ditching of the residential market'' over the ''past few years'' as Mr Freeman concludes supported by his 1982 quotation.

**Mike Brown**
**Technical Director**
**Telemap Group Ltd**

Mr. Freeman replies:
*As to the first point of Mr. Brown's letter, ''Videotex'' was a generic term suggested initially by the CCITT (International Telephone & Telegraph Consultative Committee) in the 1970s. At that time, ''Videotex'' was used to describe both uni-directional broadcast information systems, typified by the British ''CEEFAX'' and ''ORACLE'' systems, and the bi-directional interactive information systems, typified by ''Prestel'' in the UK, France's ''Teletel'', Canada's ''Telidon'', etc. Since that time, the term ''Teletext'' has come to be associated with uni-directional systems, leaving ''Videotex'' to become synonymous with bi-directional media, of which ''Prestel'' is a representative example.*
*Now to Mr. Brown's second (and more important) point. Micronet is, by nature, an ethusiasts' medium requiring a modem and microcomputer. This is simply not the kind of market/set-up the Post Office and associated information providers originally envisaged. It must be remembered that ''Prestel'' equipment was seen as being sold over the counter in the same manner as television sets, hi-fi equipment, and other consumer goods. Re-read my article, Mr. Brown, where you will find a market penetration forecast of over 4 million sets in use by the end of 1987 and then look at your high-street electronic goods or chain stores: where are the ''Prestel'' sets? Where are the plug-in adaptors? This type of man-in-the-street market is simply not there. With the exception of Micronet's excellent example, there has been no rush by information providers to stimulate such a market.*
*Look at the projected figures and look at today's reality as portrayed in Mr. Brown's figures: a ''Prestel'' user base of 50,000 with 17,000 Micronet subscribers. Now consider how many homes have television and/or telephone equipment. The figures, I'm afraid, speak for themselves.*

# MICROCONTROLLER-DRIVEN POWER SUPPLY — 1



**Although the use of a microcontroller in a power supply may raise some eyebrows, there are cogent reasons for it. The result, to the best of our knowledge, is simply the most advanced power supply project ever published by an electronics magazine. Its complexity and cost, however, make it really only suitable for advanced constructors. Furthermore, the microcontroller, an Intel 8751, can only be programmed in our design department.**

The use of a microcontroller in a power supply may be questioned for good reasons. There are, however, a number of arguments in favour of the use of such a device. Consider, for example, important benefits such as accuracy, ease of use, and the availability of functions that are virtually impossible to realize without resorting to complex analogue and/or digital circuits. One of these functions is the ability of the power supply to be integrated in a computer-controlled test and measurement system. Such systems are increasingly being brought into operation in professional electronics laboratories. Arguably, there is no reason why the use of automated control of test equipment can not be furthered in the many home workshops and smaller engineering departments.

A further advantage offered by the microcontroller is the considerable reduction of the number of components in relation to a conventional microprocessor-based control system that uses separate building blocks for CPU, EPROM, RAM, parallel/serial I/O and real-time clock.

All control functions in the power supply described here are handled by the microcontroller, in combination with relatively simple digital support circuits. The following are the main tasks assigned to the Type 8751 controller:

- setting and measuring voltage and current;
- measuring temperature in the power stage;
- driving six 7-segment displays, two LED bars and a number of LEDs;
- scanning the keyboard;
- communicating with another computer.

The controller has all the necessary software and hardware on board, obviating the need for external components such as display decoders, bus buffers and peripherals for the microprocessor.

We think it fair to warn readers that the complexity and cost of the proposed instrument make it suitable for advanced constructors with a professional background only. Also, the supply incorporates a good number of relatively new, high-grade, components. In the past, it has appeared that it often takes considerable time for distributors and retailers to start stocking such devices. Since the total cost of the power supply is still only a fraction of that of similar,

commercially available, instruments, the design is of particular interest for technical colleges, electronics laboratories, and engineering, research and design departments.
Even if it is not intended to build this high-performance power supply, it is still worth while to study its operation in detail to see what has become possible with state-of-the art components and design methods.

## General layout

The block diagram of the power supply is shown in Fig. 1. The actual work in the supply is done by the completely analogue current/voltage regulator. This is essentially a conventional series regulator provided with adjustable current limiting. One peculiarity of this circuit, however, is that the regulator is connected to ground at the + output of the supply. This arrangement has to do with the internal operation of the regulator, and is of no practical consequence to the user.
The interface between regulator and microcontroller is, of course, formed by D-A (digital-to-analogue) and A-D (analogue-to-digital) converters. The DACs take the function of precision potentiometers, so that voltage and current setting is effected by the microcontroller. The ADCs, in combination with an analogue multiplexer, measure output current, output voltage, and temperature of the power output stage. These quantities are converted to digital for processing by the microcontroller.

The 8751 communicates with the user and the control computer via six 7-segment displays, 2 LED arrays, 14 LEDs, 9 membrane switches, a digital contact encoder for setting output voltage and current limit onset, and a bidirectional serial interface.
The EEPROM shown in the block diagram is used for permanent storage of three user-defined instrument settings for a period of 10 years (guaranteed minimum).

## MICROCONTROLLER-DRIVEN POWER SUPPLY

**Technical Specification:**

- Precision regulated DC power supply.
- Output voltage range: 0 . . . 30 V. Setting via front-panel control, or via serial interface (10 mV/step).
- Current limit range: 0 . . . 2.5 A. Setting via front-panel control, or via serial interface (10 mA/step).
- Output ripple and noise at maximum load: <2 $mV_{pp}$.
- Load regulation: <2 $mV_{pp}$ for 0 . . . 100% variation of load current.

**Display and keyboard:**

- 3-digit 7-segment LED display for indication of set or actual output voltage.
- 3-digit 7-segment LED display for indication of set current limit or actual load current.
- Analogue indication of actual output voltage and current on two 10-LED bars. Current limit and set voltage are displayed on a dot scale.
- Storage of 3 power supply settings (voltage, current and slope of voltage change) in internal memory (SEEPROM).
- Automatic power-up and power-down timer forces output to 0 V to prevent spurious pulses being applied to the load.
- Output voltage can be set to 0 V by pressing associated key with LED indication.
- Fast or slow (0.5 s) change from actual to newly programmed output voltage.
- HOLD function (with LED indication) enables changing front-panel or memory-resident settings without affecting existing settings on supply output.
- LEDs indicate actuation of current limiter, thermal protection and/or serial interface.

**Design:**

- Microcontroller Type 8751 (Intel).
- Voltage control: 12-bit D-A converter Type PM7548.
- Current control: 8-bit D-A converter Type DAC0831.
- Internal precision 5 V reference: Type REF-02.
- Current, voltage and heat-sink temperature converted to digital by 12-bit D-A converter Type TL501C.
- Two-stage thermal protection with LED indication and automatic supply shut-down capability.
- Quasi-analogue setting of voltage and current by digital contact encoder.
- 10-year storage in 16×16 bit SEEPROM of 3×3 user-defined supply settings.
- Automatic dissipation limiter selects lower unregulated input voltage at $U_o$<10 V.

**Serial interface:**

- 9600 bits/s, 8 data bits, 2 stop bits, no parity bit (this serial format is supported by virtually all modern computers).
- Simple, effective control of several power supplies or intelligent test equipment via a single serial channel. Each instrument can be addressed and identified by a specific code.
- Communication with or without echo.
- Device status can be called up by controlling computer.
- All power supply functions, except internal memory, can be programmed externally via the serial interface.
- Central computer can read set and actual values of supply voltage and current, and status of thermal protection circuit.
- Front-panel controls and serial interface operate simultaneously.
- Option for mutual locking of front-panel controls and serial interface.
- Control commands are verified by syntax checker.
- Opto-coupler for complete galvanic insulation.

## Operation of the regulator

The circuit diagram of the analogue part of the microcontroller-driven power supply is given in Fig. 2. Particular attention should be paid to the various ground lines. It was already stated that the + output is ground of the power stage, but there is more to this. Actually, there are four separate ground lines in the circuit:

- DIS for the display sections;
- D for the digital circuits;
- AA for the D-A converters and associated circuits;
- AB for the measurement and control circuits.

These ground lines are connected at suitable points in the circuit to prevent supply currents interfering with internal signals for measurement and control.
The use of four ground lines complicates the internal power supply of the instrument, and makes it necessary to obtain power from a toroidal transformer with multiple secondary windings. It is, of course, possible to use three separate transformers instead of the multi-voltage type, but this inevitably results in increased size and weight of the power supply.
The internal power supply is composed of three sections that are of fairly conventional design. Displays and digital circuits are fed from a 5 V supply, opamps from a ±12 V supply, and the power stage from an unregulated high-current supply. The microcontroller energizes a relay that halves the input voltage to the power stage at low values of the output voltage. This arrangement effectively reduces the dissipation in series regulators $T_4$ and $T_5$. Regulation of the output voltage is effected by opamp IC1, which draws a portion of the base current of $T_4$ and $T_5$ via $D_3$. Output current limiting is effected similarly via $D_4$. With $R_{16}$, these two diodes form an OR gate that enables

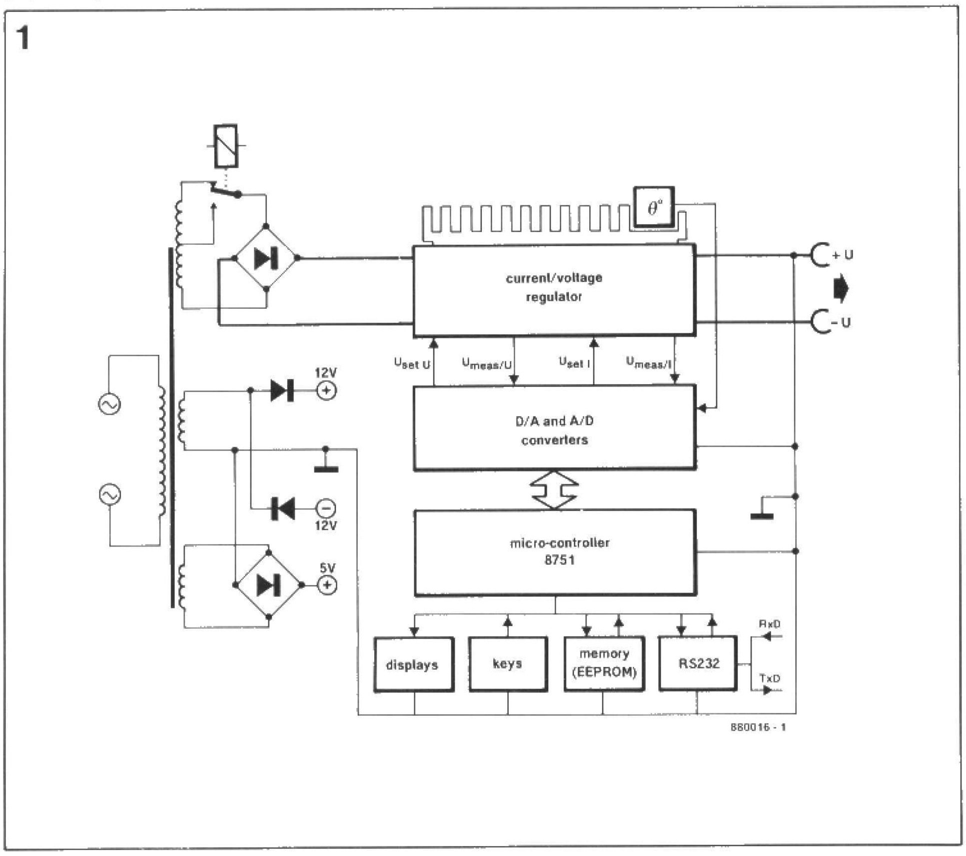



**Fig. 1. Basic set-up of the microcontroller-driven power supply.**

voltage and current adjustment to operate on the same power stage. It is important to note that ground of the regulation circuit (±12 V) and that of the digital circuits (5 V) are at the potential of the supply's positive output terminal. This means that the complete regulation circuit floats at the supply output voltage (0...30 V). The two operational amplifiers are fed from a symmetrical supply to ensure that output voltage and current can be regulated from 0 V onwards. The function of $IC_1$ is to compare $U_{SET\,U}$ (supplied by the microcontroller via a DAC) to the actual output voltage of the supply.

The operation of regulator $IC_1$ is fairly complex, and, therefore, best explained with reference to Fig. 3. For convenience's sake, the flow of the three main currents is shown in dotted, dashed and dotted/dashed lines, while $A_1$ and $T_x$ are considered to form a power operational amplifier. It is seen that this is configured as a voltage follower, because the positive output is fed back to the − input of $A_1$. This creates a regulator that is accurate by virtue of the high open loop gain of the opamp, and fast by virtue of the relatively large power bandwidth. Since an opamp with negative feedback will adjust its output voltage until it sees equal voltages at its + and − inputs, it follows that the current through $R_x$ equals the voltage supplied by the DAC divided by $R_x$. It is convenient to call this current $I_{REF}$.
Assuming that $A_1$ is an ideal opamp, it draws an input current of nought. This means that $I_{REF}$ flows entirely through $R_y$, which consequently causes a voltage drop $I_{REF}R_y$, or $(U_{DAC}/R_x)R_y$. Since there is, ideally, no voltage difference between the non-inverting and inverting input of $A_1$, the voltage on $R_y$ equals that between the positive output of the supply and ground. Hence

$$U_{out} = U_{Ry} = U_{DAC}(R_y/R_x)$$

In other words, the supply output voltage is proportional to the control voltage $U_{DAC}$.
For the following it is assumed that the regulation circuit has not yet stabilized. This happens when, for example, a short-circuit on the output has just been removed. Voltage $U_+$ is more positive than $U_-$ ($U_+ - U_- = U_{DAC}$). This causes an increase in the output voltage of $A_1$ with respect to ground, which is at potential $U_{out}$ (+ output). $T_1$ starts to conduct: the base current flow is indicated by the dotted line. The collector-emitter current of $T_1$ (dashed line) through $R_x$ and $R_y$ reduces the difference between $U_+$ and $U_-$ ($R_x$ causes a voltage drop). Therefore, the supply adjusts the output voltage until this stabilizes when $U_+$ equals $U_-$. It should be realized that this is an extremely fast process. When the circuit is loaded by $R_L$, the base and collector-emitter currents increase. The resulting supply current is shown as the dotted and dashed line.

Regulation of the output current is less complex than that of the output voltage. The voltage on $R_9$ and $R_{10}$ is compared to control voltage $U_{SET\,I}$ in $IC_2$. $U_{SET\,I}$ is provided by the microcontroller with the aid of a DAC. As long as the output current remains below the user-defined onset point of the current limiter, the output voltage of the opamp is nearly the positive supply voltage (+12 V) because the current limiter control voltage at the non-inverting input of $IC_2$ is higher than the drop caused by $R_9$ and $R_{10}$, which carry the output current. As soon as the drop across the current sensing resistors equals the control voltage, the output of $IC_2$ drops to a low level, reducing the base drive of the series transistors, and so preventing a further increase of the output current. LED $I_{REG}$ lights to indicate this condition.

Diode $D_6$ has a protective function: it prevents reverse voltage on the series transistors rising above 0.6 V. In the absence of this diode, the charged output capacitor could cause damage to the power supply when this is set to 0 V. Protection is also required against external voltages being applied to the supply when this is switched off.
Capacitors $C_{13}$ and $C_{17}$, and power resistor $R_{20}$, are included to ensure stable operation of the regulator. The resistor is a dummy load connected ahead of the current sensing resistors. It enables the output capacitor to be discharged when the supply does not power a load.
Current sensing resistors $R_9$ and $R_{10}$ are close-tolerance power types (4 or 5 W; max. 90 ppm). Standard power resistors (900 ppm) are unsuitable here, and give rise to regulator instability.

Temperature sensor Type LM335Z is mounted in thermal contact with the regulator transistors, and supplies a temperature proportional voltage of 10 mV/K. When the temperature limit of 55 °C is reached, the corresponding LED on the front panel starts to flash.

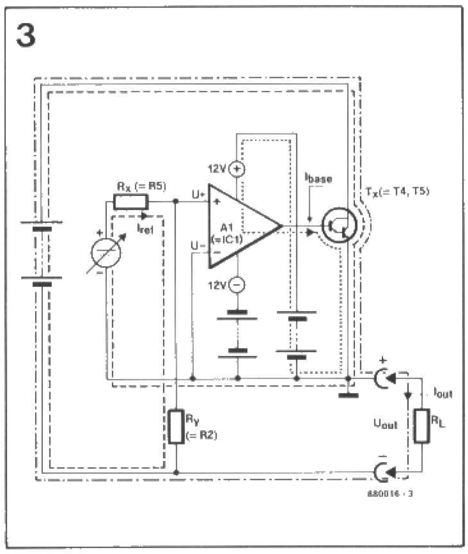



**Fig. 3. Essential operation of the regulator circuit.**

2

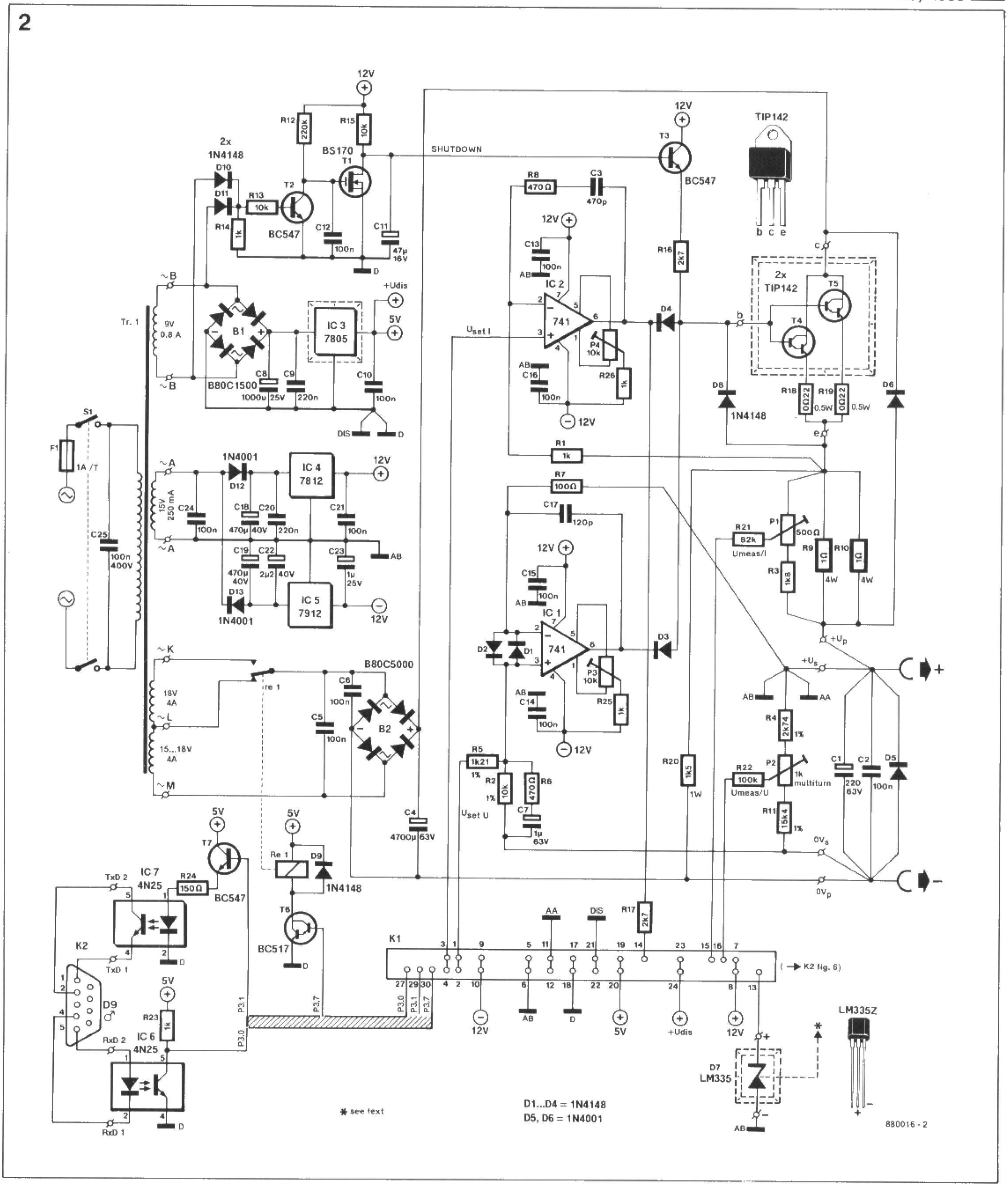


Fig. 2. Analogue part of the power supply. Note the use of no fewer than four different ground levels.

When the temperature rises above 65 °C, this LED keeps flashing, but the LED in the 0 V OUT membrane key is illuminated, and the output voltage is arranged to drop to nought. The above temperature levels may appear relatively low, but they reduce the risk of users being scalded by the heatsink. Once the thermal protection circuit is active, a supply voltage other than nought can not be restored until the heatsink temperature has dropped below 65 °C.

A ground terminal is not provided on the front panel of the supply. It is, however, a simple matter to fit this on rear panel of the enclosure. The same goes for the SENSE terminals: $U_+$ and $U_s$ may be used separately as will be detailed in part 2 of this article.

Voltages $U_{MEAS/U}$ and $U_{MEAS/I}$ are taken from presets to enable the read-out to indicate the range of these settings. The two measuring voltages are of opposite polarity: $U_{MEAS/I}$ is positive with respect to ground of the measuring circuit (output terminal +), while $U_{MEAS/U}$ is negative. These polarities will be reverted to in the description of the analogue-to-digital converter.

## Automatic dissipation limiter

The large range of the output voltage (0...30 V) requires dividing it in two sub-ranges to prevent excessive dissipation of the series regulators at relatively low output voltages and high current. It will be recalled that power dissipation is the product of the voltage across the series regulators and the output current supplied. The mains transformer in the supply has two 15...18 V windings, which are connected in series. An SPDT relay contact, $re_{1a}$, connects either the 15 V or the 30 V winding to the input of power rectifier $B_1$. The voltage selection relay is arranged to switch to the low input voltage when the set output voltage is lower than 10 V, while the 30 V input is selected when the set output voltage is higher than 11 V. The hysteresis of 1 V prevents oscillation of the switching circuit when the output voltage varies around the above values. The voltage reduction relay is controlled by the 8751 via darlington driver $T_6$.

Readers may wonder why the power reduction circuit operates on the basis of the *set*, rather than the *measured* (actual) output voltage of the supply. The following discussion provides the answer in the form of an example and an illustration.

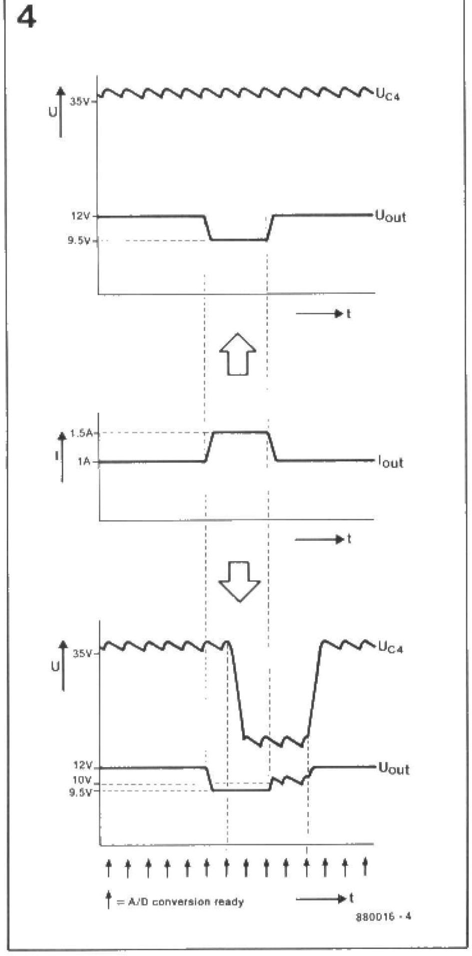



**Fig. 4. The use of the set, rather than the actual, output voltage for controlling the activity of the dissipation limiter prevents dips and ripple on the supply output.**

Assume the set voltage and current to be 12 V and 1.5 A respectively. When the load current rises above 1.5 A, the current limiter is activated, and the output voltage drops. Further assume that this stablilizes at 9.5 V, which is below the switching threshold of the dissipation limiter. Were this to operate on the measured output voltage, the relay would toggle, selecting the low voltage winding on the transformer.

Taking this a little further, it is assumed that the output current has just dropped below the set shutdown level. Normally, the output voltage would rise instantly, but in this case it has to "wait" for the end of the next analogue-to-digital conversion of the output voltage before the processor is actually informed that this is below the threshold for input voltage reduction. Meanwhile, the regulation circuit has considerable difficulty maintaining the set output voltage, because the relay does not toggle as yet to feed it with the higher unregulated input voltage. Consequently, considerable ripple may briefly appear on the output voltage, which is unacceptable for many applications. The lower V/I curve in Fig. 4 illustrates this effect.

The above discussion explains the use of the set output voltage for controlling the automatic dissipation limiter in the supply. Evidently, this is mainly to prevent the relatively slow A-D conversion of the measured output voltage upsetting the normal operation of the power supply. In this context, it is useful to note that the supply is thermally protected against damage caused by a continuous short-circuit on the output.

The mains transformer in the supply has four separate secondary windings:

- 8...10 V; 750 mA for digital circuits and the voltage drop detector powered by the internal 5 V regulator;
- 15 V; 150 mA for the symmetrical 12 V supply that powers the opamps;
- 2×15...18 V; 4 A for the power stage.

## Power on-off delay

One of the most important characteristics of a power supply is that its output voltage is free from spurious transients generated during the switch-on and switch-off instants. In the present design, additional complicating factors are present in the form of the microcontroller, the DACs and ADCs, and the operational amplifiers in the D-A conversion circuit.

Recently, integrated circuits have been developed to aid in controlling power-on and power-off behaviour of analogue and digital circuits. These new, protective, ICs are essentially fast comparators. In the present design, however, a discrete circuit is used as a simple and cost-effective alternative—see Fig. 5.

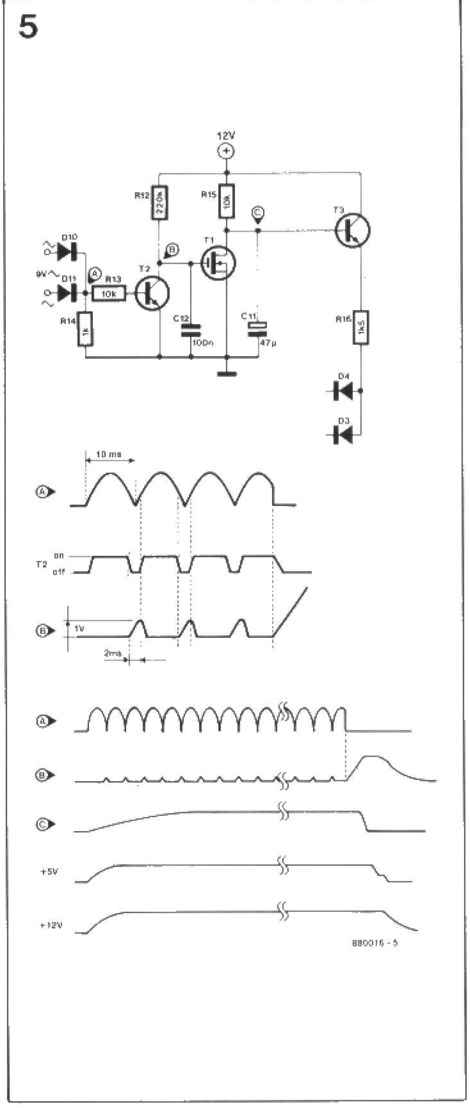



**Fig. 5. The power-up and power-down timer prevents spurious voltage transitions on the supply output.**

When power is applied, electrolytic capacitor $C_{11}$ in the shut-down circuit is initially discharged, keeping $T_3$ switched off so that the supply output voltage is nought. The ripple at the base of $T_2$ causes this transistor to be off for 2 ms only during the zero-crossings of the mains voltage. This effectively prevents the voltage on $C_{12}$ increasing to more than about 1 V. Hence, Bi-FET $T_1$ remains off, and $T_3$ does not start to conduct until after about 2 s when $C_{11}$ is charged via $R_{15}$. The polarization of the base voltage of the series regulator transistors is now assured, and the power supply can be taken into normal service. When the rectified voltage disappears from the base of $T_2$, $C_{12}$ is rapidly discharged. FET $T_1$ effectively short-circuits $C_{11}$ and so turns off the output transistors via $T_3$. This process is completed within a few tens of milliseconds. Meanwhile, the supply voltage for the microcontroller and the A-D and D-A converters has not yet dropped below the critical level, so that spurious behaviour of these circuits is not translated in dangerous dips or peaks in the voltage applied to the load.

## Digital control circuit

All the functions available in the Type 8751 microcontroller from Intel have been exploited to the full in the present design. The 4 Kbyte ROM on board the chip contains the control program, while the 128 bytes RAM is used for storage of temporary variables. The UART (universal asynchronous receiver/transmitter) is programmed to handle the bidirectional serial communication with the external control computer, and timers 0 and 1 to take care of all process timing. In addition, all available I/O lines are used for direct control of peripherals (display, keyboard, non-volatile programmable memory, converters and input multiplexer).

The microcontroller used belongs in the MCS51 family discussed in [1].

The circuit diagram of the digital control circuit is shown in Fig. 6. The 8 lines of port P0 function as databus for the D-A converters, and as I/O lines for the display unit (common-anode). Port 1 controls the common-cathode displays, and reads the keys on the front panel. Lines P0.0 and P0.1 in addition function as serial input/output lines for the SEEPROM.

A number of lines on port P2 are programmed as keyboard scan lines and chip select lines for the D-A converters and the SEEPROM. The $\overline{WR}$ (write) signal for the two DACs is provided by line P3.6, which is also used to clock the serial EEPROM, whose chip select is provided by P2.5. Lines P2.6 and P2.7 control the multiplexing of the voltages supplied by the current, temperature and voltage measurement circuits. P2.3, in combination with $D_{12}$... $D_{14}$ incl. is programmed to arrange the address coding of the supply on the serial port.

6

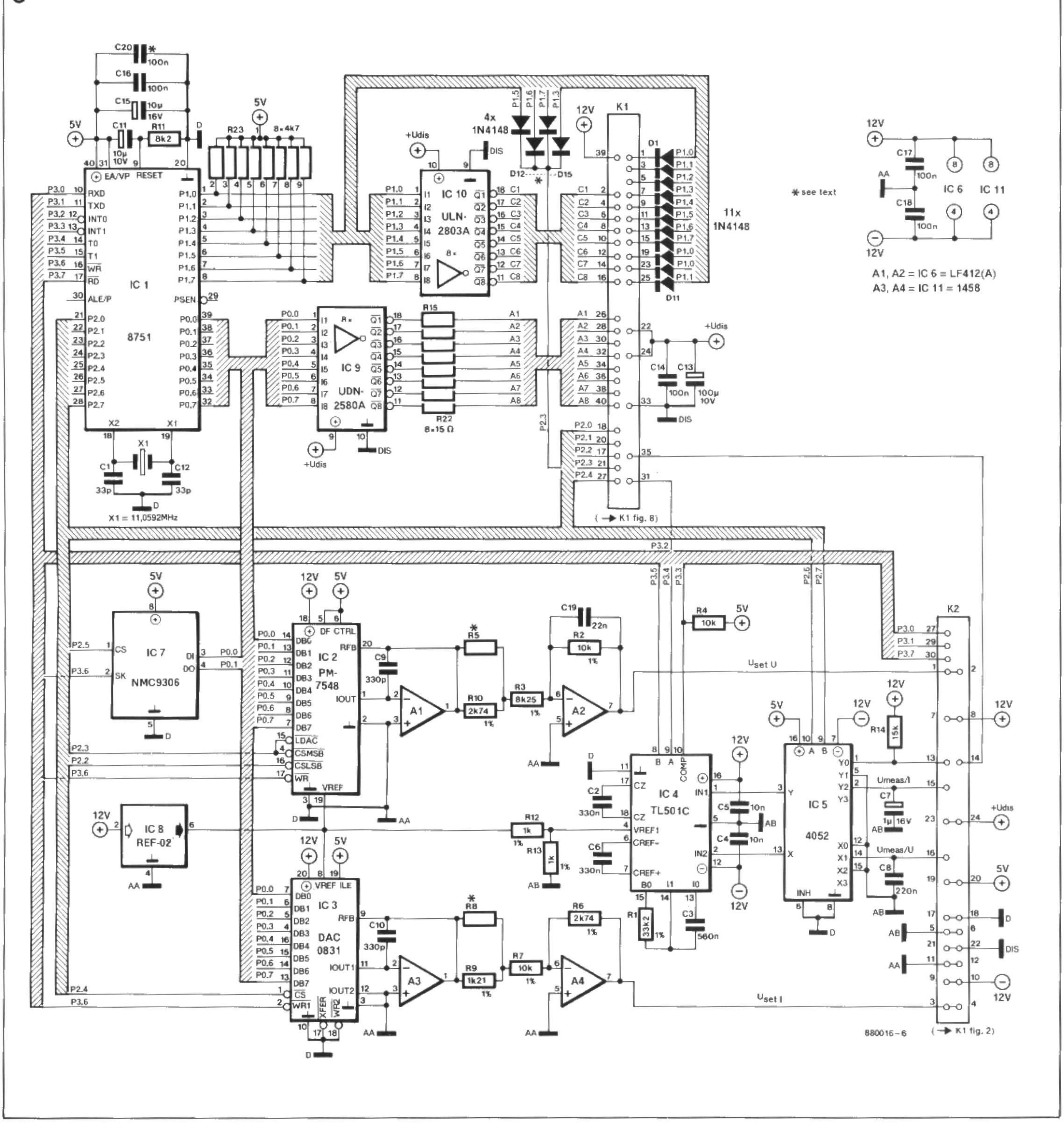


**Fig. 6. The digital control circuit in the power supply is based around a powerful microcontroller and precision A-D and D-A converters.**

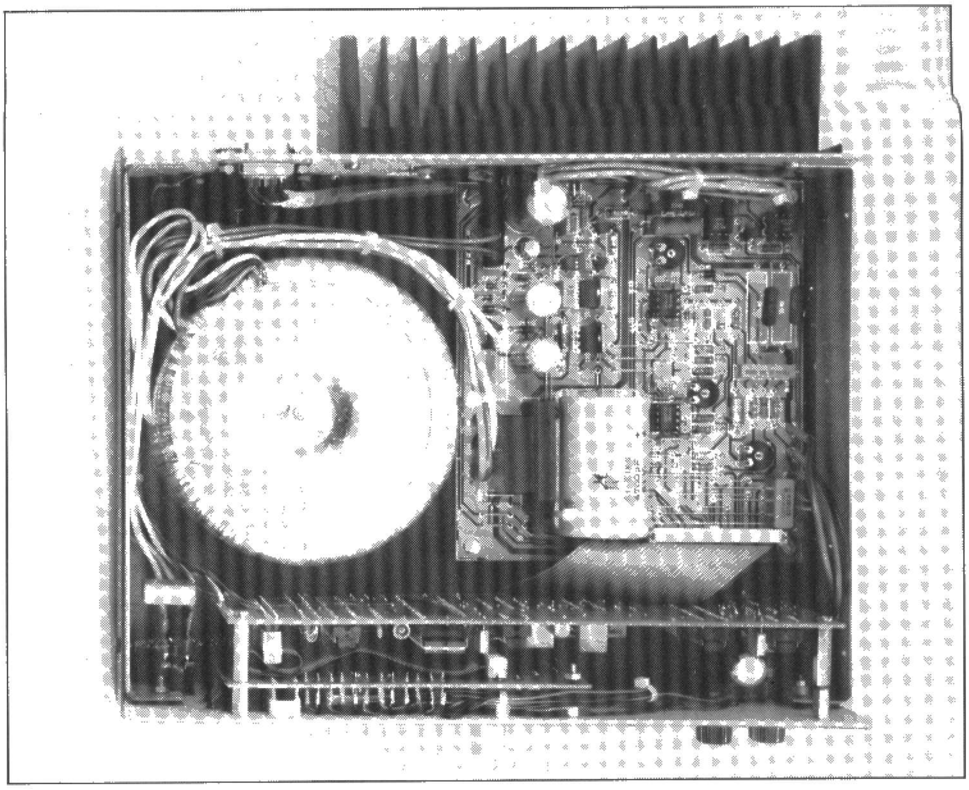
The final design of the supply is clearly a trade-off between hardware constraints and efficient software. To make things absolutely clear: the control program resident in the microcontroller has been developed by *Elektor Electronics*.

A precision voltage source Type REF-02 supplies a reference voltage of 5 V (±20 ppm) for the D-A and A-D converters. The REF-02 keeps the deviation of the supply output voltage down to a maximum of ±20 mV at $U_o$=30 V (a typical deviation of ±10 mV was measured in prototypes).
The gain of the second inverter on each SET output is not exactly unity, but its function is to compensate the inversion incurred in the first amplifier, which functions as a current-to-voltage converter.

The analogue and digital grounds are kept separate throughout the circuit, and are not connected anywhere except at the D-A converters, where optimum accuracy is needed. The actual voltage regulator is $IC_2$, a Type PM7548 12-bit digital-to-analogue converter that can be driven from an 8-bit databus. The current limiter circuit can do with lower resolution, and is, therefore, set up around an 8-bit converter chip Type DAC0835. The actual output voltage, the voltage caused by the output current, and the voltage supplied by the temperature sensor are applied to a single ADC Type TL501C ($IC_4$) via analogue muliplexer $IC_5$. The microcontroller determines which of the three signals is fed to the ADC. Each of three multiplexed voltages is converted to digital approximately 5 times per second.
Output COMP of the ADC drives interrupt input ($INT_1$) on the microcontroller. There are two further interrupt sources in the circuit:

- timer 0: displays and DACs are refreshed at 1.1 ms intervals;
- timer 1: serial interrupt.

The connection of $U_{MEAS/I}$ and $U_{MEAS/U}$ to dual analogue multiplexer Type 4052 may appear unusual at first, but the use of inputs X1 and Y2 in combination with the grounded inputs Y1 and X2 effects the required inversion of the measurement signals. It will be recalled that the digital ground is at the same potential as the positive output of the supply, and floats at 0...30 V depending on the set value of $U_o$. The current measurement voltage is positive with respect to this ground, just as the temperature measurement voltage, applied to Y0 of the multiplexer, while X0 is grounded. The output voltage of potential divider $R_4$-$P_2$-$R_{11}$ in the circuit of Fig. 2 is, however, *negative* with respect to the same ground, so that inversion is required in $IC_5$ before the signal can be applied to the ADC chip.



**Top view of a prototype of the supply. Note the sandwich construction of the digital and display/keyboard circuits.**

## Dual slope conversion

The three previously mentioned analogue quantities are converted to digital for processing by the microcontroller in a so-called *dual-slope* conversion process. The conversion duration is measured by the controller with the aid of an interrupt timing routine. This arrangement may appear unnecessarily complex and time consuming, but it requires only software, not a costly converter that supplies the 12-bit binary code after conversion is completed.
The principle of dual-slope conversion is relatively simple. Initially, a capacitor is charged with the measured voltage during a period determined by the microcontroller. This is called integration of the input value of the converter (first slope). Next, the capacitor is discharged by a constant current (second slope) until a comparator toggles to indicate that discharging is complete. The microcontroller measures the discharge time, and uses this for computing the value of the input voltage. The basic principles of this process are illustrated in the drawing of Fig. 7. The final accuracy of the measurement is independent of the absulute duration of the slopes: what counts is the *ratio* of their durations. Since the microcontroller clock frequency is fixed and accurately known, the duration of the second slope suffices for deducing the value of the input voltage. Interestingly, the TL501C is intended by the manufacturer, Texas Instruments, as the analogue building block in an A-D conversion system that comprises the Type TL502 or TL503 as the complementary digital part. In the present application, however, the microcontroller takes over the digital driving of the TL501C.

7

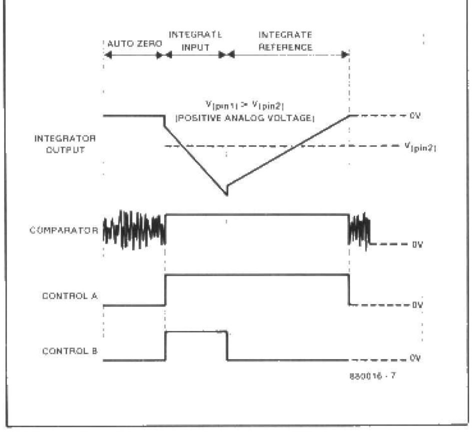
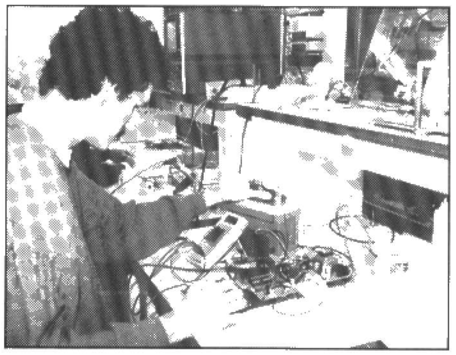



**Fig. 7. Dual slope analogue-to-digital conversion under microprocessor control.**

## Data retention

The Type NMC9306 in position $IC_7$ is a *serial electrically erasable programmable read-only memory* (SEEPROM or $SE^2$PROM) with a capacity of 16×16 bits and an on-board step-up converter for the programming voltage. As indicated in the abbreviation SEEPROM, the device can be erased by applying a control voltage instead of exposing it to ultra-violet light. Remarkably, it has a serial input and output, so that it can be housed in an enclosure with only 8 pins. Erasure of the contents and programming of new data in the device is ar-

ranged by the microcontroller.
This data retention device is used for non-volatile storage of three programmes, i.e., control settings of the power supply. These are the set output voltage, current limit level, and the output voltage response (fast or slow slope): in all, 3×3 parameters that can be stored in the SEEPROM. Programme 1 is automatically selected on power-up, but the 3 loaded and displayed parameters are not put into effect by the relevant circuitry until the user overrides the 0 V OUT function, which is always in operation when the supply is powered up or reset. The non-volatile memory in the power supply provides flexibility and ease of use. The user has the settings saved on a previous occasion available immediately for use again at power-on. The SEEPROM used is stated to be capable of 10,000 programming cycles. This corresponds to more than ten years of use when programmed twice a day. Data retention is also guaranteed for 10 years minimum. The device recognizes 9 instructions whose execution is timed by an external clock signal applied to input SK. Reading is effected by instruction READ and a serially applied address. The byte at this address is returned serially via data output DO. Programming is achieved by sending instructions EWEN (erase/write enable) and EWDS (erase/write disable). Prior to writing to a SEEPROM register, this must be cleared by electric erasure: instruction ERASE is sent, followed by the relevant register address. This reads all logic ones when it is not programmed. Writing is effected by instruction WRITE and the relevant 16-bit dataword.
Four lines suffice for communicating with the SEEPROM: serial data out, serial data in (datawords are organized as 16 bits), clock and chip select. The SEEPROM further recognizes single instructions for erasure of all data, and writing the same data to all 16 registers.



**The designer, Peter Theunissen, is seen here in the *Elektor Electronics* laboratory working on an early prototype of the supply.**

## Display and keyboard

The proposed power supply is remarkable for its ability to display both the *set* and the *actually measured* output voltage and current. The former are displayed when the user changes the settings, i.e., when operating the rotary contact encoder or the U/I switch.
The circuit diagram of the controls and display section is shown in Fig. 8. All decoding and demultiplexing is done by the microcontroller. Two LED bars (LD1; LD5) permanently indicate the trend of either the set voltage and current, or the measured voltage and current. The resolution of the bars is, of course, not sufficient for accurate readings, but they enable spotting, for instance, a short-circuit literally at a glance. The LED bar that indicates voltage has two scales printed at opposite sides on the front panel foil. A LED lights automatically to indicate which scale is used. The ranges are

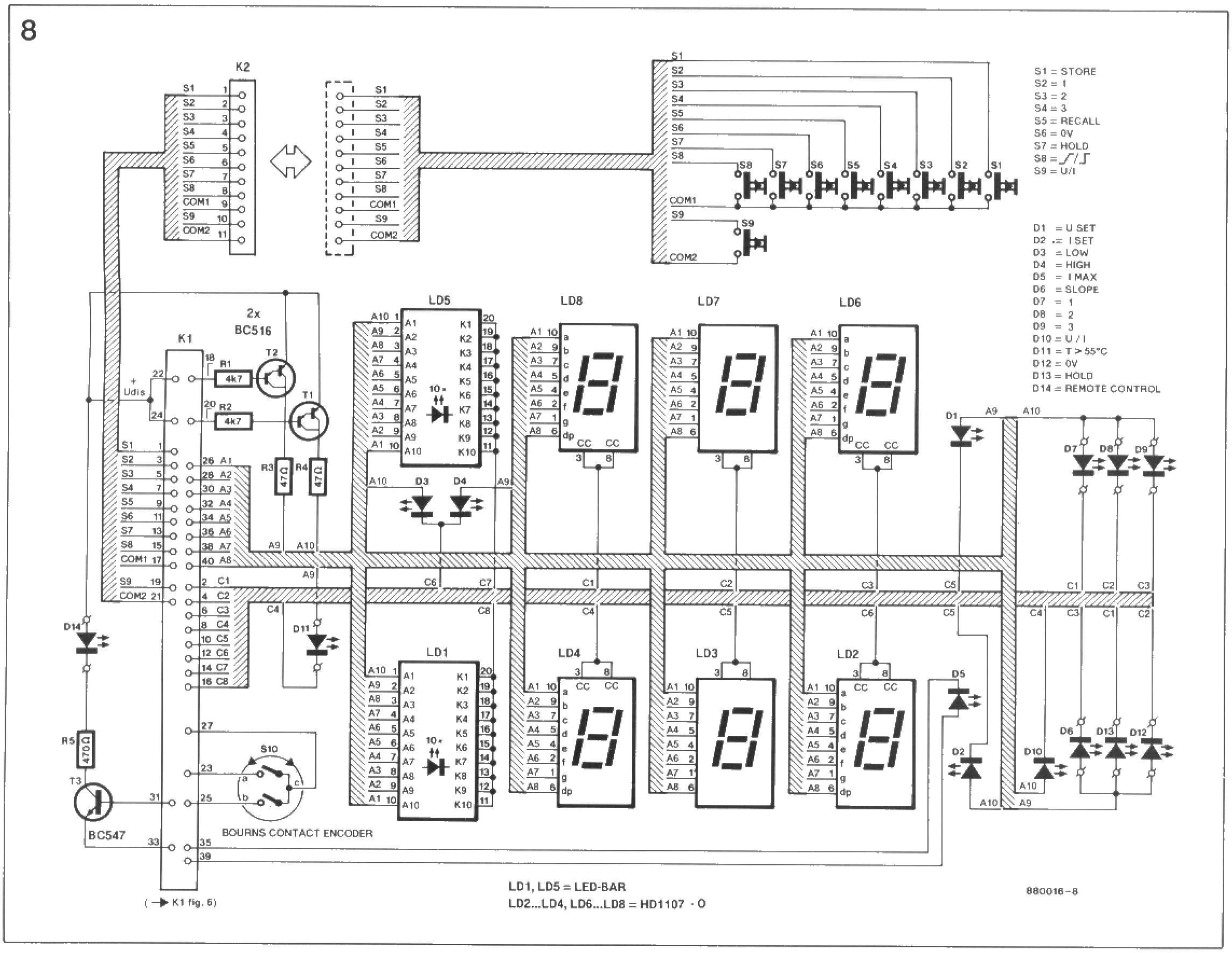



**Fig. 8. Display and keyboard circuits.**

0...10 V (1 LED per volt) and 10...30 V (non-linear scale).
The keys for selecting the various settings of the power supply are membrane types built into the front panel foil. The microcontroller scans the keys for activity via lines S1...S9 incl. and COM1-COM2.

The digital contact encoder used for the voltage and current setting is essentially an ergonomic substitute for a thumbwheel switch. The device supplies a 2-bit Gray code to indicate the direction of travel. Inside the encoder, two switches (channel A and B) are operated by a common spindle. Opening and closing in a specific order, the switches provide the 2-bit code shown in Fig. 9 (clockwise operation). One complete spindle rotation corresponds to 24 or 36 pulses. There is no mechanical end stop, and the microcontroller is programmed to deduce the direction and magnitude of travel by means of the pulses it receives from the contact encoder.
The manufacturer of the digital contact encoder, Bourns, supplies types with 24 or 36 detent positions per spindle revolution. Both can be used in the present circuit, but the 36-position type is preferred over the 24-position type because the latter requires 18 full spindle revolutions to cover the voltage range of 0...30 V.

Next month's instalment of this article will deal with the construction, setting up and operation of the microcontroller-driven power supply.

**Reference:**
(1) Single-chip microcontrollers. *Elektor Electronics*, September 1987.

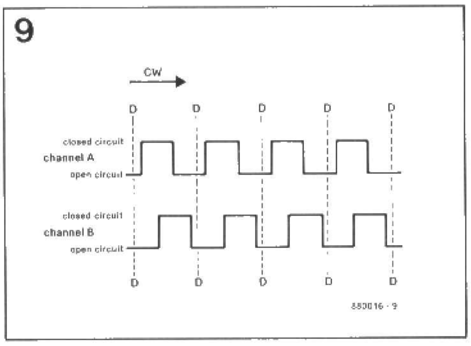
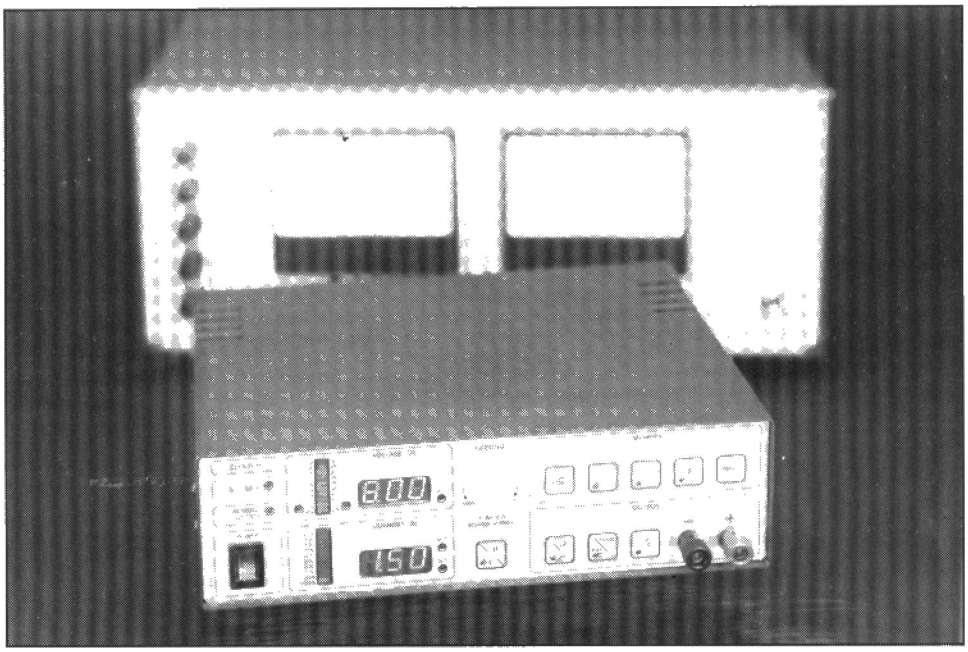



**Fig. 9. The phase difference between pulses on channel A and B of the digital contact encoder is used for deducing the direction of travel.**



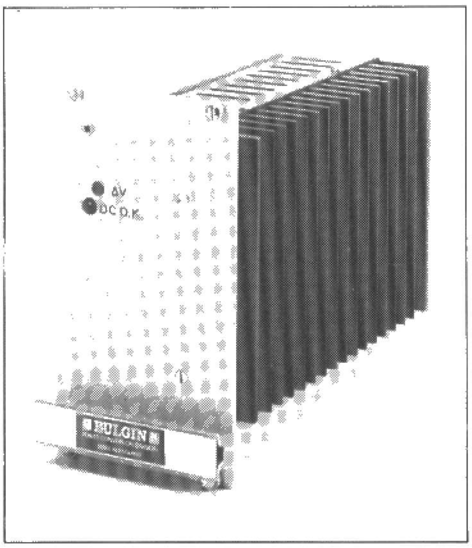
# GEN. INTEREST NEWS

## Electrex Supreme Award for Response

The Electrex Supreme Award for Advanced Technology was won by Response Company Ltd of Winchester for its Calmu-3 Credit and Load Management Unit. This is a radioteleswitch controlled, communicating, multi-tariff electricity supply meter. By using signals sent out via BBC radio transmitters, supplies of electricity can be controlled as necessary.
The Supreme Award is not confined to micro-electronics. The judges at the recent Electrex Exhibition were looking for a break-through into new technology or an extension of existing technology, whether it be in design or in the use of new materials or new technologies.
Other award winners were:
Federal Electric Ltd for its Solid-state, Electronic Controlled Circuit Breaker;
Elkay Electrical Manufacturing Co. Ltd. for its Sensoround — a passive infra-red energy controlling sensor;
Victor Products PLC for its "Light Guide", a new concept in linear lighting;
Eaton-Williams Products Ltd. for its Air Condition Monitor;
Megger Instruments Ltd. for its PDA1 Power Disturbance Analyser.

## Full power for Cirkit

Cirkit Distribution now offer the full range of Bulgin Power Conversion products, which will normally be ex-stock.
The product range comprises DC-DC encapsulated convertors (3-15 W); Eurocard DC-DC convertors (40-100 W); linear encapsulated power supplies (1-5 W); and a series of linear supplies in Eurocard format up to 250 W.
Cirkit supply small quantities with no minimum order value and are able to offer generous discounts for OEM quantities.
Cirkit Distribution Ltd • Park Lane • BROXBOURNE EN10 7NQ • Telephone (0992) 444111.




**A 100 W DC-DC euromodule, one of the Bulgin Power Conversion products now available from Cirkit.**

## Co-fired multilayer circuits

An evaluation of low temperature, co-fired ceramic multilayer circuit technology is to be untertaken by ERA Technology.
The emergence of the new technology is in response to the continuing trend towards very large scale integration (VLSI), where electronic devices, more densely packed in silicon are required to operate at ever higher speeds. There is, therefore, increasing pressure to develop interconnection media external to the chip which is also densely packed and which does not degrade system performance, particularly speed.
Further information from ERA Technology Ltd • Cleeve Road • LEATHERHEAD KT22 7SA • Telephone (0372) 374151.

# MAKING THE WEATHER WORK FOR YOU

**The past 10 years or so have seen what are probably the greatest advances ever in weather forecasting. Certainly they are the greatest in terms of potential value of forecasts to commerce and industry.**

by Dr John Houghton, Director-General and David Houghton, Marketing Director, UK Meteorological Office, Bracknell

First to appreciate how big are the benefits from better weather forecasts have been the world's airlines, traditionally the customers who work most closely with the meteorologists. This was highlighted last year when a team of scientists from the UK Meteorological Office received the prestigious Royal Society ESSO Energy Award, in recognition of their pioneering contribution to energy saving through developing the world's best operational weather forecasting model. By international agreement the world's airlines have access to flight forecasting information for all parts of the world from the Meteorological Office headquarters at Bracknell, typically information on winds and temperatures at all the heights at which aircraft fly. Airlines using Bracknell data together spend over £5000 million every year on aviation fuel, so the saving of one per cent or more in fuel consumption which can be achieved through using the better forecasts is not inconsiderable.

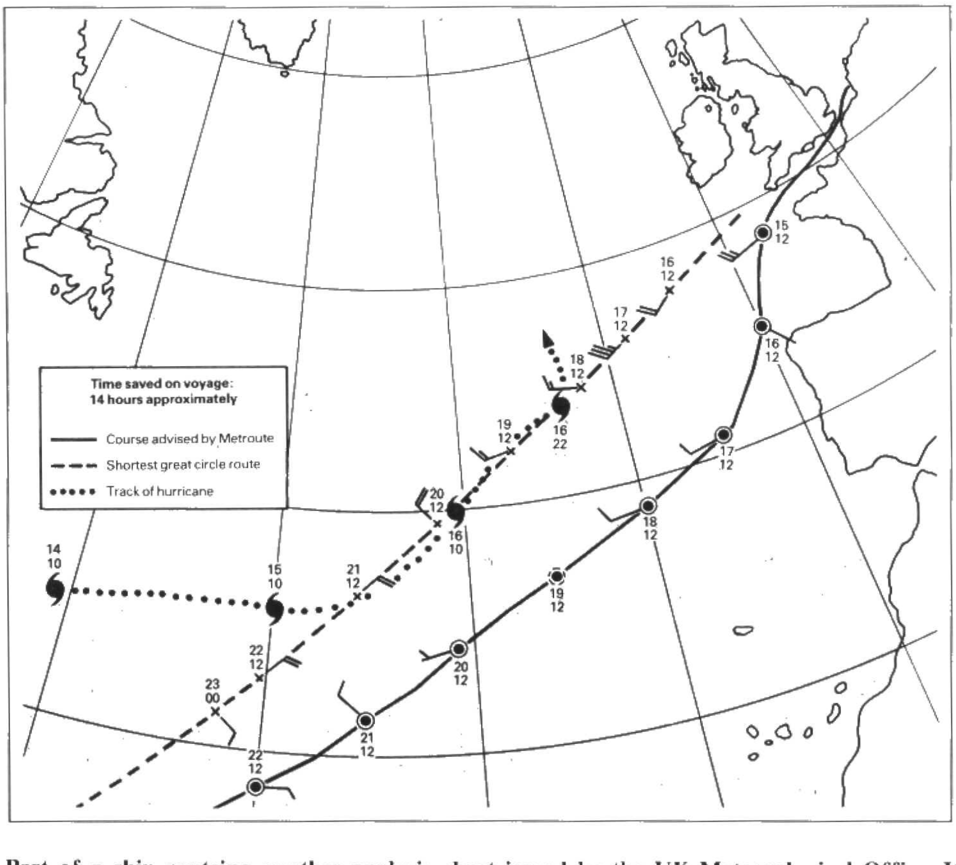
Forecasts contribute to fuel saving in a variety of ways. For instance, a forecast can indicate the position of the strongest tail wind so that the aircraft can be flown to take advantage of it and thereby achieve a higher speed relative to the ground, saving both time and fuel. Forecasts of temperature are also important, for air temperature influences the efficiency of the jet engines. It is possible only to conjecture on the much larger savings achieved in comparison with using no weather forecasts at all.

## Global approach

Airlines are interested only in short period forecasts, for up to 24 hours ahead at the most. However, recent improvement in weather forecasting is even more evident in predictions for two, three, four and five days ahead. Until 1971 forecasts for more than two days ahead were of little practical use, certainly not in commercial terms. Then a new 10-level forecasting model was introduced, and the quality of forecasts for days two and three rose dramatically. But the model was only hemispheric: there was neither the computing capacity nor the observing system capable of supporting a global model; indeed, it was thought at the time that over a few days the weather over one hemisphere was largely independent of the weather over the other. The latest global models of atmospheric behaviour have demonstrated that it is not so. Accurate forecasting beyond a day or two demands a totally global approach, which has been made possible through parallel advances in computing, new observing systems using both geostationary and polar orbiting satellites, and mathematical modelling of the global atmosphere. The first illustration shows how all these elements combine to provide a global forecast. The result is that today's forecasts for three to six days ahead are better by two days than were forecasts only 10 years ago.

The acid test in any forecasting system is its ability to predict change. In the second illustration this test is applied to forecasts produced here for the area covering Europe and the North Atlantic. The element tested is surface pressure, the forecast surface surface pressure against the observed surface pressure. It can be seen that forecasts for day three are now as good as those for day one were 10 years ago, day four as good as day two, and so on.

Many sectors of industry and commerce can also derive considerable financial benefit from these better forecasts. But this benefit is yet to be fully realised because the forecaster is still largely




**Part of a ship routeing weather analysis chart issued by the UK Meteorological Office. It covers a voyage by a chemical tanker of 13 000 tonnes which left Rotterdam on 13 August 1986 bound for Trinidad. The recommended Metroute enabled the vessel to avoid the worst of the weather caused by remnants of hurricane *Claudette* and thereby save about 14 hours on passage. Figures against charted positions show the date and hour of observations, and the 'feathered' lines indicate the direction and force of the wind towards those points. Each full feather stroke indicates a wind speed of ten knots and each half stroke five knots.**

unaware of the user's requirements, and the potential user is still largely unaware of what information the forecaster can provide. What is required is a marketing dialogue similar to that which has been taking place between the meteorologists and the aviators for some 70 years. The aviator has not been slow to tell the meteorologists what information he requires, and the meteorologist has responded to the best of his ability by deriving increasingly better methods of producing and communicating the required information.

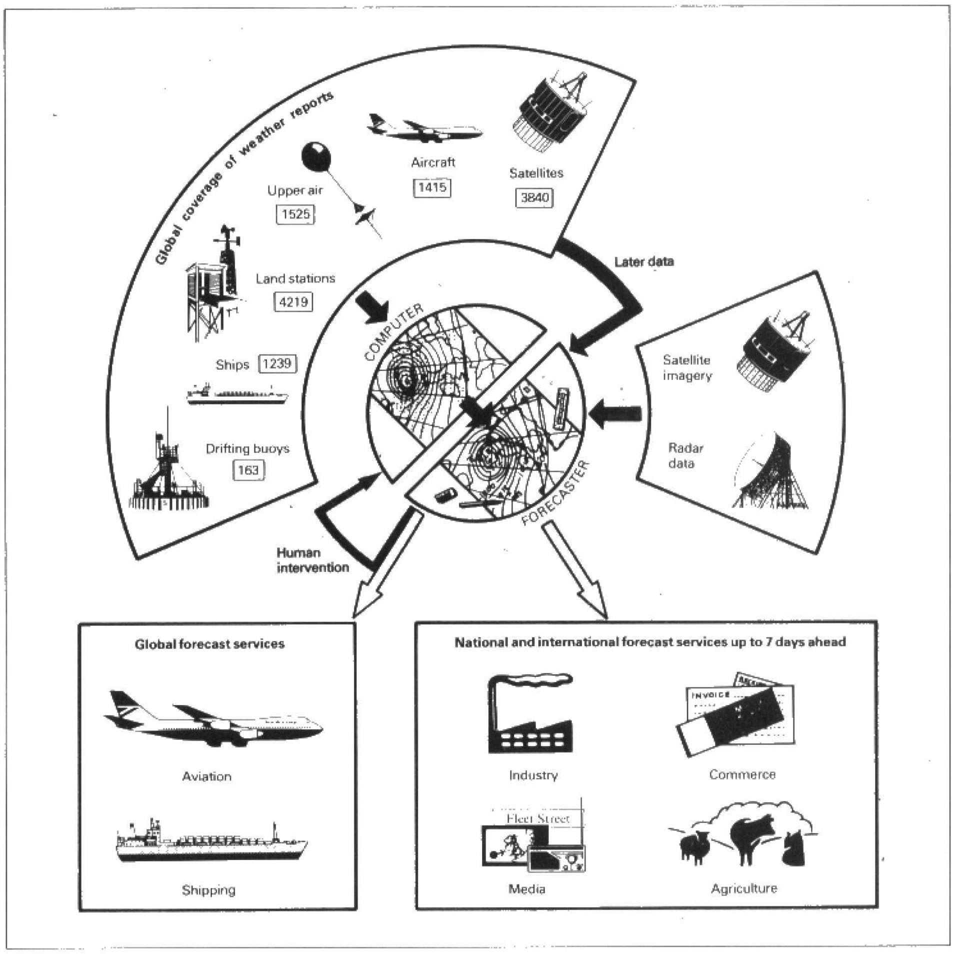
## Ship routeing

The shipping industry are even older customers for weather information: in fact, the Meteorological Office was set up around 1855 specifically with the purpose of giving warnings of storms to ships at sea. Nevertheless, in contrast to airlines, shipping companies have been slow to appreciate the opportunities for saving time and money by using specialist routeing advice. Only a small proportion of shipping uses a ship routeing service, although the benefits have been shown to be great. The diagram on the front page shows the routeing of a ship across the Atlantic for a minimum-time crossing. The saving achieved by avoiding adverse weather was 14 hours. Ships can also be routed on the basis of minimum wave height if, for instance, the comfort of passengers or animals is paramount.

Offshore drilling operations, especially from floating platforms, are the most weather-sensitive activities at sea. High winds and swell can be particularly dangerous for drilling and diving operations, or when platforms are being moved or towed. The cost of operating a platform is high, of the order of £1 million per week, and the value of accurate forecasts of weather and waves for a few days ahead is also high. Forecasters working on oil rigs are a vital part of the operational team.

One of the better known forecasting successes of 1986 was the record breaking achievements of the *Virgin Atlantic Challenger*. An accurate four-day weather forecast was essential, and the signal to go followed a favourable forecast from our Central Forecasting Office.

The value of a weather forecast to the aviator and the sailor is almost assumed, because they are open to the elements. The farmer is another obvious customer, though traditionally he has been regarded as so experienced a weather observer that he can rival the professional forecaster. But even for him things have changed. Now, for the first time, he is able to schedule many of his farm operations several days in advance. Armed with specialist forecasting and climatological advice, he can sow his seeds, apply his fertilizers and preventive sprays, and harvest his crops, all at times to get the best yields.




**Steps from observation to forecast. Numbers indicate the average number of observations each day for use in the main 0000 utc and 1200 utc global numerical forecast model runs.**

## Matching forecast to demand

As with other marketing business, the first aim in marketing weather forecasts is that the provider and the user be brought together to their mutual benefit. The product is weather information, both historical and forecast, specified and assembled to meet the needs of the user. Experience has shown that the majority of users of weather information cannot afford either the time or the effort to glean the information required for a particular operation by attemping to interpret a general weather summary and forecast. The full benefits which may come from weather information are reaped only when the information is tailored to the particular requirement. For example, anyone who sells umbrellas is interested only in whether it will rain at a time of day when people are likely to want to be out of doors. A manufacturer of heating equipment is vitally concerned with temperature and, because it takes several days of cold weather before demand is stimulated, he wants a package comprising both historical and forecast information. The food retailer requires a particularly complex and comprehensive package relating the expected weather to various factors, for instance to variations in demand for a wide variety of foodstuffs, to variations in their availability if they are grown in the field, and to the ease with which they can be transported and stored. To benefit most in such cases, forecast and historical information have to be assembled so as to relate as closely as possible to the procedures for making decisions throughout the industry.

The second essential marketing consideration is how to convey weather information efficiently to the user. Should it go by digital link, facsimile or telephone; to the company headquarters, the local office or the building site? If the means of communication or the destination are wrong or inappropriate the information may be of little practical value.

Third, the price must be right. Price setting is the part of the marketing mix which many scientists will try to avoid as being at best unscientific and at worst immoral. But in this context it is not only necessary to pay for the resources devoted to the provision of the service; the price must also relate directly to the perceived value of the service. The recipient of specially tailored weather information is much more likely to use it to advantage if the cost bears some sensible relation to the benefit which may be derived. It is not that the price needs to be

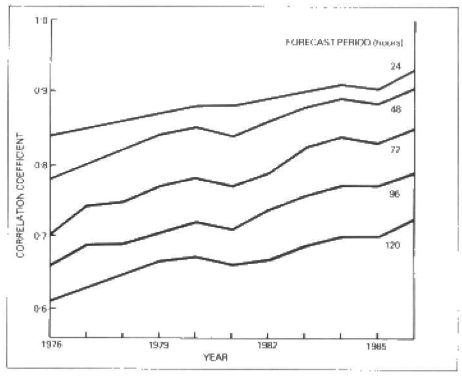
high — just realistic. In practice, the price of most meteorological services is only a small percentage of the benefits derived, which makes a weather service a necessity rather than a luxury. This applies not only to individual services but on the scale of national meteorological services, too. The contribution of every such service to a nation's economy is many times the cost of the service.

## Public communications

The value of weather forecasts for the public at large through newspapers, radio and television must not be overlooked. They enable people to make millions of small decisions that contribute significantly to the well-being of the community and to the efficient and effective use of its resources. For the man in the street the weather forecast may sometimes do no more than satisfy his curiosity regarding the future. On certain occasions it contributes significantly to his comfort and convenience. He can go out wearing suitable clothes and footwear, and not carrying an umbrella unless he really needs one. On at least a few days each year the forecast confers a measurable benefit. For example, he may save fuel by avoiding a leisure trip to the coast or mountains that would have been spoilt by bad weather. Just as for specialist users, the amount and quality of weather information useful to the average citizen has increased greatly in the last few years, so much so that new means have had to be found for him to reap the benefit and for the meteorological service to reap some rewards. In Britain, a new telephone information service known as Weathercall has recently been introduced. It costs more than the average rate of charge for a call and a proportion of the charge to the subscriber is paid to the meteorological service. A similar service, Marinecall, is available to inshore sailors. It provides detailed forecasts over 15 consecutive telephone numbers, each for a sector of the coast around Britain.

There are, of course, many other areas of industry and commerce where weather forecasts properly applied can contribute to profitability and efficiency. In the power industry weather information is essential to short and long term planning; highway authorities make huge savings during the winter by applying grit and salt only when there is advance warning that it is necessary. In building, construction, transport, manufacturing, maintenance and repair, many activities and processes are weather sensitive; and the demands for goods and services vary with the weather. The World Meteorological Organization is working to obtain better estimates of the benefits of weather services throughout the world, both to communities as a whole and to individual sectors. In the UK, a conservative estimate is that the total benefit is well over 10 times the total cost of the service.

Today, computer models give good detailed weather information up to five or six days ahead. As the models improve and as larger computers become available, the period of forecasts will perhaps be extended to 10 or even 14 days. The question then will be how predicatable is the atmospheric circulation beyond two weeks ahead? Almost certainly it cannot be forecast in detail. Nevertheless, there is a good possibility that the average character of the weather a month or two ahead may be predictable. The economic value of such predictions, even if they are not perfect, would be very large. So the stakes are high and the world is waiting on the meteorologists to tackle the problem of weather forecasting at longer range, for which they will require at the very least the next generation of supercomputers. All told, one thing is certain, the weather service is no longer seen as a luxury but a necessity.




**Annual average correlations between 24, 48, 72, 96 and 120 hours forecasts and actual pressure changes at sea level for the North Atlantic Region since 1976.**

# GEN. INTEREST NEWS

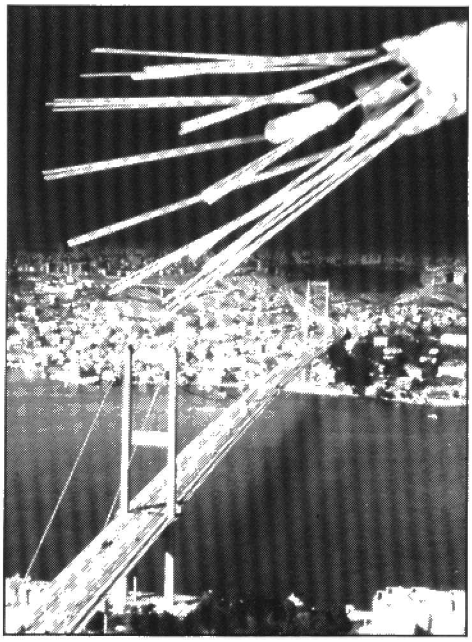
## BEP acquired by Elsevier

Benn Electronic Publications have been acquired by Elsevier Advanced Technology Group, part of the international communications group, Elsevier Science Publishers.

Renamed BEP Data Services, the company will continue to publish the *Microelectronics Journal, Journal of Semicustom ICs, Semicustom IC Yearbook, IC International, European Electronics Component Distributor Directory*, and the *Yearbook of World Electronics Data*.

Elsevier Science Publishers specialize in fulfilling the information needs of senior technical, commercial, and corporate managers in the manufacturing industry and related service institutions.

Elsevier Advanced Technology Group • Mayfield House • 256 Banbury Road • OXFORD OX2 7DH • Telephone (0865) 310156/512242.



**Communications link between Europe and Asia using the most modern facilities: Siemens have laid two fibre-optic cables with 20 fibres each along the Bosporus bridge in Istanbul. The link will enable more than 150,000 telephone conversations to be conducted simultaneously between east and west. (*Siemens Press Photograph*).**

## Lightning is a coming

During August last year, we passed through the zero point in the eleven-year cycle of sunspot activity, and over the next five years can expect a rise in activity — and a corresponding increase in lightning strikes (of the 100 MV driving potential; 200 kA stroke current; and with arc energy of 100 MW/m type). Such lightning strikes can cause havoc to unprotected computer and other microprocessor controlled electronic equipment.

If a surge protection device is designed to fail safe by automatically disconnecting the mains from such equipment, it will have achieved its object of protecting that equipment, but at the expense of continuity of the mains supply.

One method of providing surge and spike protection, and yet continuing to provide power, is to install a plug-to-plug compatible uninterruptible power supply (UPS) from Avel Lindberg, such as the AD 1000.

Contact Avel Lindberg Ltd • SOUTH OCKENDON RM15 5TD • Telephone (0708) 853444.

# COMPONENT NEWS

## Recovery in chip industry

Semiconductor companies fared better in 1987 than they have since the market slump, according to Dataquest. Many companies grew faster than the market, some showing growth rates that doubled and even trebled the overall industry growth rate.

Dataquest estimates that semiconductor revenue grew 24.3 per cent over 1986 to reach $36.6 billion. Japanese companies had 48% of the world market; North American companies 21.7%; and European companies 11%.

| RANK | | | REVENUES | | |
|---|---|---|---|---|---|
| 1986 | 1987 | COMPANY | 1986 | 1987 | % CHANGE |
| 1 | 1 | NEC | 2,638 | 3,193 | 21.0% |
| 3 | 2 | Toshiba | 2,276 | 2,939 | 29.1% |
| 2 | 3 | Hitachi | 2,307 | 2,781 | 20.5% |
| 4 | 4 | Motorola | 2,025 | 2,450 | 21.0% |
| 5 | 5 | Texas Instruments | 1,781 | 2,125 | 19.3% |
| 6 | 6 | Fujitsu | 1,365 | 1,899 | 39.1% |
| 8 | 7 | Philips-Signetics | 1,258 | 1,597 | 26.9% |
| 11 | 8 | Intel | 991 | 1,500 | 51.4% |
| 10 | 9 | Mitsubishi | 1,136 | 1,481 | 30.4% |
| 9 | 10 | Matsushita | 1,206 | 1,479 | 22.6% |

Note: All revenues rounded  source: Dataquest

**Top ten semiconductor suppliers world-wide.**

| | 1986 | 1987 | Annual Growth |
|---|---|---|---|
| Philips-Signetics | $ 820 | $ 969 | 18% |
| * SGS Thomson (1) | 546 | 535 | (2%) |
| Texas Instruments | 489 | 525 | 7% |
| Motorola | 425 | 501 | 18% |
| * Siemens (2) | 396 | 446 | 13% |
| * National Fairchild (3) | 338 | 382 | 13% |
| Intel | 214 | 295 | 38% |
| NEC | 229 | 258 | 13% |
| * AMD-MMI (4) | 220 | 246 | 12% |
| ITT | 215 | 243 | 13% |

**Top ten European semiconductor suppliers.**

## Erwin Sick devices from STC Electronics Services

STC Electronic Services now stock a comprehensive range of sensing products from Erwin Sick, Europe's leading manufacturer of advanced photoelectric control devices.

Full information from: **STC Electronic Services • Edinburgh Way • HARLOW CM20 2DF • Telephone (0279) 626777.**

## Philips–ES2 agreement

Philips Components and European Silicon Structures have reached agreement which ensures customers world-wide of rapid prototyping and high volumes of ASICs implemented in Philips' standard 1.5 micrometre dual layer metal CMOS processes (followed by 1.2 $\mu$m towards the end of this year). ES2 will apply these processes to its proprietary E-beam direct-write technology for fast prototypes and low volumes in its recently-opened factory in Aix-en-Provence.

Further information from: **European Silicon Structures • Mount Lane • BRACKNELL RG12 3DY • Telephone (0344) 52 52 52.**

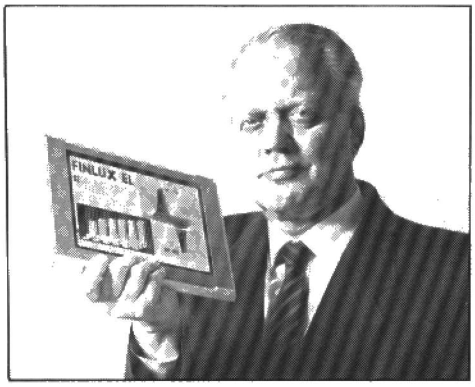
## House of Power–NEC agreement

One of the world's largest manufacturers of tantalum capacitors, NEC, has appointed House of Power to distribute its range of tantalum bead devices throughout the UK.

**House of Power • Electron House • Cray Avenue • ORPINGTON BR5 3PN • Telephone (0689) 71531.**

## Finlux in flat-screen development

The Finnish company of Finlux has been appointed to lead a project for the development of flat-screen displays under the RACE (Research and Development in Advanced Communications Technologies in Europe) programme.




Finlux already has considerable experience in flat-screen development and presented the first European flat-screen monochrome wall-mounted TV receiver last year (see *Elektor Electronics*, October 1987, p.17).

Further information from: **Lohja Corporation • Finlux Display Electronics • P.O. Box 46 • SF-02201 ESPOO • Finland • Telephone +358 0 42001.**

## New services from Greenweld

Greenweld now operate an in-store credit card, with the choice of an option or a budget account. This enables customers to just pick up the phone and order goods for dispatch the same day. Also, the company have an electronic mailbox, telex and fax facilities.

Further information from **Greenweld • 443E Millbrook Road • SOUTHAMPTON SO1 0HX • Telephone (0703) 772501/783740 • Telex 265871 MONREF G quoting 72:MAG36026 • Fax: (0703) 787555 • EMail: Telecom Gold 72:MAG36026.**

## ERSA equipment from Access Tools

The ERSA range of soldering equipment and the Pastorino range of hand tools is now available from Access Tools, a division of Toolrange Ltd. Whether you are looking for a simple screwdriver or the latest fully programmable automatic machine tool, Access can help you.

Further information from: **Access Tools • Upton Road • READING RG3 4JA • Telephone (0734) 429446.**

## Spare parts for PCB assembly holders

A spare parts facility for their WY Series PCB Assembly Holders is available from **Wybar Electronics • Unit M • Portway Industrial Estate • ANDOVER SP10 3LU • Telephone (0264) 51347/8.**

# APPLICATION NOTES

**The contents of this column are based on information obtained from manufacturers in the electronics industry, or their representatives, and do not imply practical experience by *Elektor Electronics* or its consultants.**

# SINGLE-CHIP MULTI-STANDARD COLOUR DECODER

**In areas where TV transmissions to more than one colour standard can be received, colour receivers are required which can handle multistandard transmissions without additional manual switching. This requirement will greatly increase with the introduction of satellite TV.**

Such receivers have, in the past, incorporated a multi-standard colour decoder (MSD) using several integrated circuits to automatically select the standard of the received signal. However, the growing need for these MSDs makes it economically and technically desirable to incorporate all the active parts in one IC and to reduce, as far as possible, the external circuitry.

This application note describes two new single-chip MSDs using bipolar technology, the TDA4555 and TDA4556. The ICs are similar except for the polarity of the colour difference signals at the output. The TDA4555 provides −(R−Y) and −(B−Y) signals; the TDA4556 provides +(R−Y) and +(B−Y) signals. Only the TDA4555 will be described.

The ICs are universally applicable and allow the design of a range of TV receivers having a common main chassis. Automatic selection of the required standard has been made more reliable and the maximum time required for identification and switching is a little over half a second.

When reception is difficult because signals are weak, noisy, or badly distorted, the automatic standard recognition (ASR) can be switched off and the standard chosen manually.

Figure 1 is a block diagram of a typical multi-standard colour decoder incorporating the TDA4555. The composite video input signal (CVBS) is fed via switchable filters to the input of the MSD. The filters separate the chrominance and luminance signals according to the standard selected, which, for ASR, is controlled by the colour decoder IC.

Chrominance signals from the filters are AC coupled to the input of the TDA4555, which produces the colour difference outputs, that are, in turn, AC coupled to the Colour Transient Improvement (CTI), part of the TDA4560. This IC also contains an adjustable delay-line formed by gyrators, so a conventional wirewound delay line is not needed.

The signals are then fed to the Video Combination IC, TDA3505, which converts the colour difference signals −(R−Y) and −(B−Y) and the luminance signal (Y) into the RGB signals. The TDA3505 also incorporates the saturation, contrast, and brightness control circuits and allows for the insertion of external RGB signals. Finally, the processed video signals are applied, via the RGB output stage to the picture tube.

The new MSD can decode colour TV signals transmitted according to the following standards:

**A. QAM** (Quadrature Amplitude Modulation of the colour carrier by the colour difference signals).

1. NTSC standards with any colour subcarrier frequency, for example
   - NTSC-M ($f_o$ = 3.579 545 MHz), referred to as NTSC-3.5
   - Non-standard NTSC systems, for example with $f_o = f_{oPAL}$ = 4.433 618 75 MHz.

   This system is used in the United Kingdom and in the Near East and is referred to as NTSC-4.4. As the colour subcarrier frequency is the same as that of the normal PAL system, the same crystal can be used without switching in the reference oscillator for both systems.

2. PAL standard, characterised by phase reversal of the (R−Y) signal on alternate scan lines. The colour subcarrier frequency for normal PAL is 4.433 618 75 MHz.

1

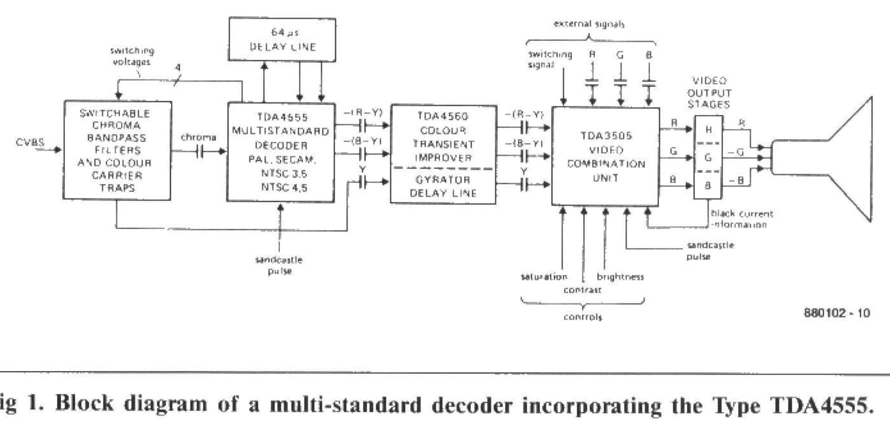



**Fig 1. Block diagram of a multi-standard decoder incorporating the Type TDA4555.**

**B. SECAM** characterised by transmission of the colour difference signals (R–Y) and (B–Y) on alternate scan lines and frequency modulation of the colour subcarriers. The frequency of the colour signals may vary between 3.900 MHz and 4.756 MHz. The frequencies of the colour subcarriers are:
$f_{oB}$ = 4.250 MHz for a ''blue line''
$f_{oR}$ = 4.406 25 MHz for a ''red line''.

With these capabilities, the new decoders can handle most of the colour TV transmissions in central Europe and also in other areas.

## TDA4555 circuit description

Figure 2 is the circuit of a multistandard colour decoder using TDA4555/56.

The IC only requires a single sandcastle pulse at pin 24 for the generation of all internal pulses (e.g. burst key, horizontal and vertical blanking pulses). The sandcastle pulse levels are >8 V for the burst key; 4.5 V for horizontal blanking: and 2.5 V for vertical blanking.

Level detectors in the sandcastle pulse detector separate the three levels which are used to generate the required key pulse and clamp pulses.

A special System Control and Standard Scanning circuit (SCSS) provides the switching voltages to set the MSD to the desired standard.

As long as no colour standard is recognized, the SCSS circuit switches the decoder sequentially to the PAL, SECAM, NTSC-3.5 and NTSC-4.4 standards. If the standard of the received signal is not recognized after four field periods (80 ms), the next decoding system is activated. This time interval, also called the standard scanning period, is a good compromise between fast switch-on of the colour and effective interference suppression with noisy signals. The maximum time between the start of scanning and switching on the colour is 360 ms, including the colour switch-on delay of two field periods. However, in the TDA4555, a PAL priority circuit is incorporated to improve the reliability for SECAM, so the scanning can last for another two scanning periods (520 ms maximum).

After recognition of a SECAM signal, the information is stored and the decoding is switched to PAL. A second SECAM recognition is only provided if no PAL recognition occurs. This gives reliable SECAM recognition when the SECAM-PAL transcoding at the source (e.g. in cable systems) is not perfect, or when PAL signals are distorted by reflections so that they simulate SECAM signals.

With b/w signals, the scanning is continuous and the colour is kept switched off because there is no standard recognition.

The switch voltage corresponding to the recognized standard ramps from 2.5 V to 6 V during scanning and the remaining switch voltages are held at 0.5 V maximum. These voltages are used to switch the filters at the input, the crystals of the reference oscillators, and the colour subcarrier traps, and also to indicate the recognised standard (e.g. by LEDs).

To prevent unnecessary restarting of scanning because of momentary disturbances (e.g. short-term interruptions of the colour signal), the TDA4555 incorporates a delay of two field periods (40 ms) before scanning can start.

Finally the IC allows the automatic standard recognition (ASR) to be switched off by applying external switching signals and forcing one of the decoding modes by applying at least 9 V to the appropriate pin (25. . .28 incl.). These pins also serve as outputs for the internally generated switch voltages which indicate the selected standard. The automatic colour switch-off is active in both cases.

The MSD must provide colour-difference output signals with an amplitude referred to a given test signal, despite amplitude variations (within

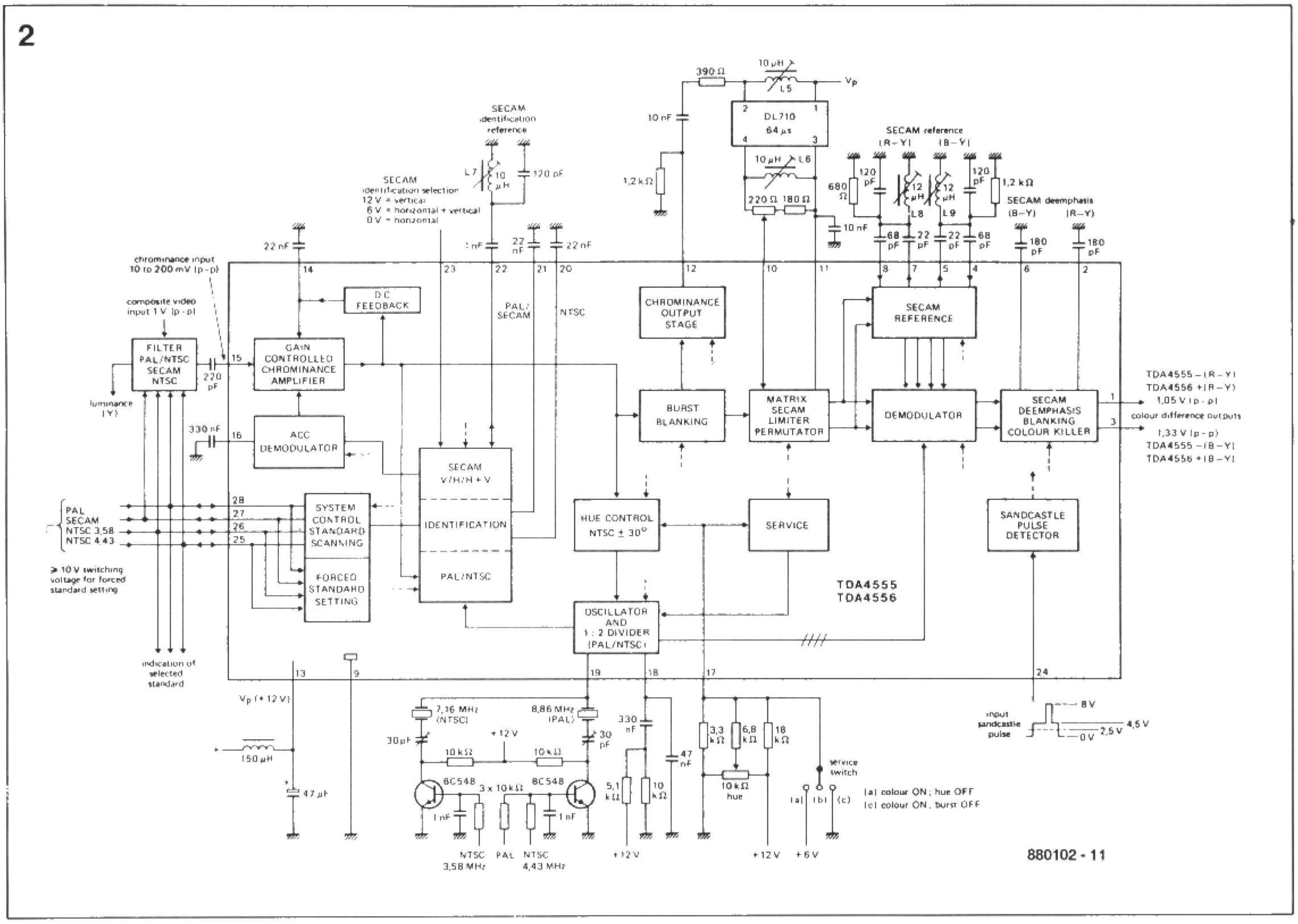



**Fig. 2. Block diagram and peripheral circuitry.**

3

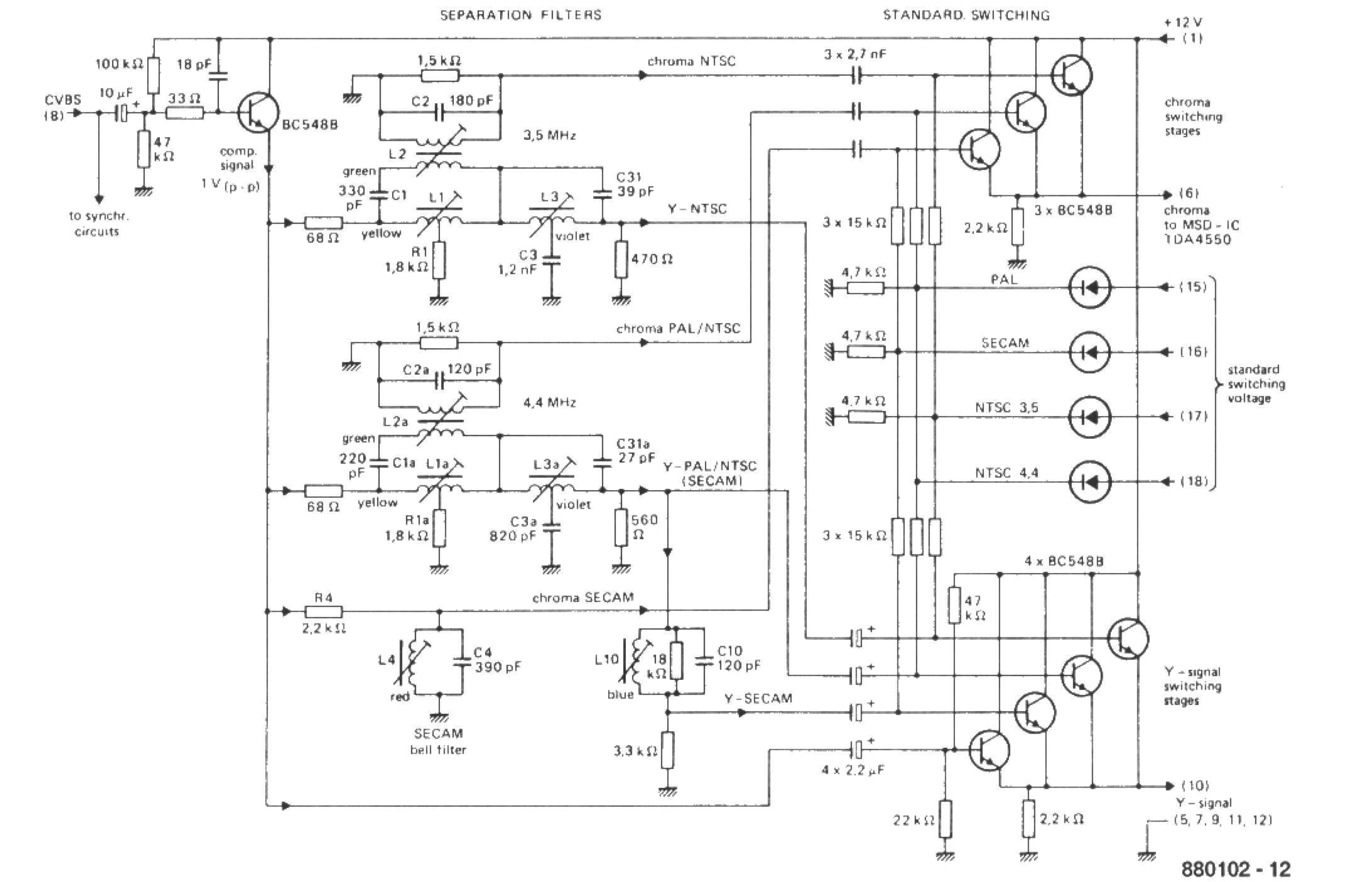



**Fig. 3. Circuit diagram of the filter input section.**

limits) of the colour input signal. This is required to maintain a fixed amplitude relationship between the luminance signal (Y) and the colour-difference signals, independent of different i.f. filters or receiver detuning. The TDA4555/56 incorporate an Automatic Colour Control circuit (ACC) for this purpose.

## Circuit example

Figure 2 is a tested circuit of a multistandard decoder. A more detailed circuit of the input filters is shown in Fig. 3. These filters separate the luminance signal (Y) from the colour signals for the four decoding modes.
The same filters can be used for PAL and NTSC-4.4 signals since they have a similar frequency spectrum. For SECAM signals, it is possible to use the 4.4 MHz subcarrier trap of the PAL/NTSC-4.4 filter but it is then necessary to add a trap tuned to about 4.05 MHz in the Y channel. This filter suppresses the colour signal components below about 4.2 MHz which mainly occur during the ''blue SECAM line''.
In the case of PAL and NTSC, the reference for the control is the burst amplitude. For SECAM, the complete colour signal is used. The colour signal is AC coupled, via pin 15, to a gain-controlled amplifier and the control voltage is obtained by in-phase synchronous demodulation of the burst or the colour-signal.
This approach has the advantage that the same demodulator, having only one external capacitor at pin 16, can be used for all standards and also results in noise reduction with noisy signals. Unwanted increase of saturation with noisy signals (colour bright-up effect) is prevented without an extra peak detector being required.

Table 1

Coil data for the multi-standard decoder of Fig. 2 and Fig. 3

| coil no | inductance (µH) | Q | toko type no. | no. of turns | colour | use |
|---|---|---|---|---|---|---|
| L1/L1a | 5.5 | >90 (4.4 MHz) | 119 LNS-A 4449 AH | 8+8 | yellow | separation filter |
| L2/LK<br>L2a/LKa | 12.5 | >90 (4.4 MHz) | 119 LNS-A 4451 DY | 24/1 | green | colour bandpass filter |
| L3<br>L3a | 66.0 | 60 (2.52 MHz) | KANS-K 4087 HU | 19+46* | violet | phase delay correction |
| L4 | 3.8 | 60 (4.4 MHz) | 113 CNS-2 K 843 EG | 17 (=14+3) | red | bell filter |
| L5, L6, L7 & L10 | 10.0 | >80 (4.4 MHz) | 119 LN-A 3753 GO | 11+11 | blue | decoder board and SECAM trap for $f_{ob}$ |
| L8, L9 | 12.0 | >80 | 119 LN-A 3753 GO | 12+12 | blue | decoder board |

*Source: Philips Technical Publication 169.*

Mullard Limited • Mullard House • Torrington Place • London WC1E 7HD. Telephone: (01 580) 6633. Distributors in the UK are listed on InfoCard 509 (*EE* May 1987).

# VLF CONVERTER

**Build this 10 MHz up-converter if you are interested in receiving signals from time standard, FAX, RTTY and other utility stations operating in the kilometric bands.**

The frequency range from 30 kHz to 150 kHz is generally referred to as the Very Low Frequency (VLF) band. It is used relatively little, because high transmitter powers and large aerial systems are required, which generally give a relatively small coverage (typically about 300 to 1000 km). For a number of applications, this is not considered a disadvantage, however. Propagation of VLF waves is highly predictable, since there is virtually no atmospheric reflection: the transmitter range is, therefore, fairly accurately defined. VLF signals travel almost exclusively via the so-called *ground wave*, while the ground-ionosphere space acts as a waveguide. Thanks to this property of the VLF band, received signals are usually free from phase shift and amplitude variation (fading), so often found on the shortwave bands. The VLF band is well suited to medium-range, one-way data communication, such as time standard transmitters (Rugby GBR, Rugby MSF, Mainflingen DCF77, Prangins HBG), meteorological facsimile, submarine communication, and telex networks. One disadvantage of the VLF band is the huge aerial system required at the transmitter side. Aerial systems of several square kilometres, and with multiple transmitter feed points, are not uncommon, yet attain a radiation efficiency of only a few percent. At the receiver side, due account should be taken of the high level of man-made noise (computers, neon tubes, TV sets and other electrical appliances). In most cases, the so-called *long wire* is the only feasible aerial at the receiver side. Thirty metres or more of sloping or horizontally running insulated wire, mounted well away from the previously mentioned sources of interference, is recommended for serious experiments in receiving VLF transmissions.

Generally, the lower the frequency, the rarer and more interesting the stations. Not every communications receiver can be tuned as low as 15 kHz, but this is made possible by the up-converter described here. It effectively converts the frequency range from about 15 kHz...300 kHz to 10 MHz, so that the CW, RTTY, FAX, AM or SSB facilities of the communication receiver tuned between 10.000 and 10.300 MHz can be exploited to receive VLF transmissions.

## Circuit description

The VLF converter is an application of the Type NE602 active double balanced mixer and oscillator, whose block diagram is shown in Fig. 1. The chip requires only a handful of external components to make a good-quality up-converter.

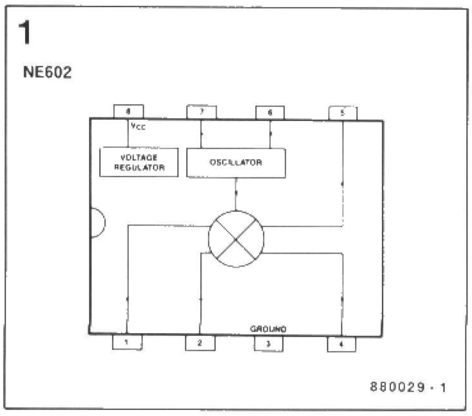



**Fig. 1. NE602 integrated active double-balanced mixer/oscillator.**

The circuit diagram of the converter is given in Fig. 2. The function of the circuit is to convert the frequency range from 15 kHz to about 300 kHz to an equally large band starting at 10 MHz. The SSB/CW/FAX/RTTY receiver connected to the output of the converter is tuned between 10.015 and 10.300 MHz. A VLF station such as Rugby MSF is, for example, "received" at 10.060 MHz. The VLF aerial signal is passed through low-pass filter $L_1$-$C_2$-$L_2$-$C_3$-$L_3$-$C_4$ that defines the input frequency range (15 kHz...300 kHz). Transistor $T_1$ forms an impedance transformer between the filter output and one RF input of the active mixer in $IC_1$. The NE602 is set up in an asymmetrical configuration here. RF input pin 2 is bypassed to ground with $C_7$, while $P_1$ is used for setting equal direct voltages at the RF inputs to optimize mixer balance. The output frequency of the local oscillator on board the NE602 is set to 10 MHz with the aid of an external quartz crystal, $X_1$. Trimmer $C_{11}$ provides a means for accurately setting the LO frequency to 10.000 MHz, so that the tuning scale on the receiver corresponds to the true received frequency, ignoring, of course, the "10" preceding the kHz digits in the read-out.

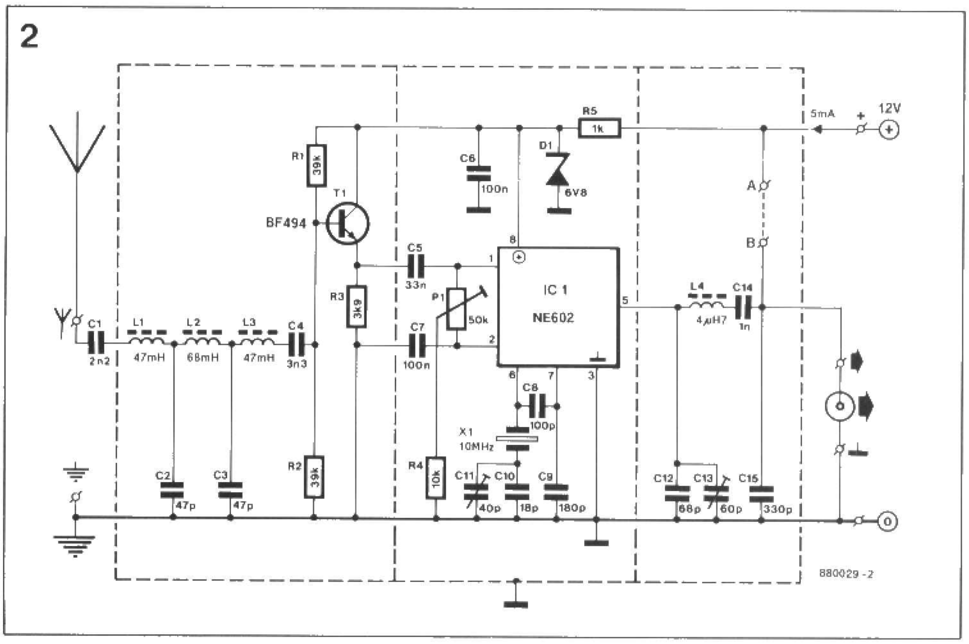



**Fig. 2. Circuit diagram of the VLF up-converter.**

3

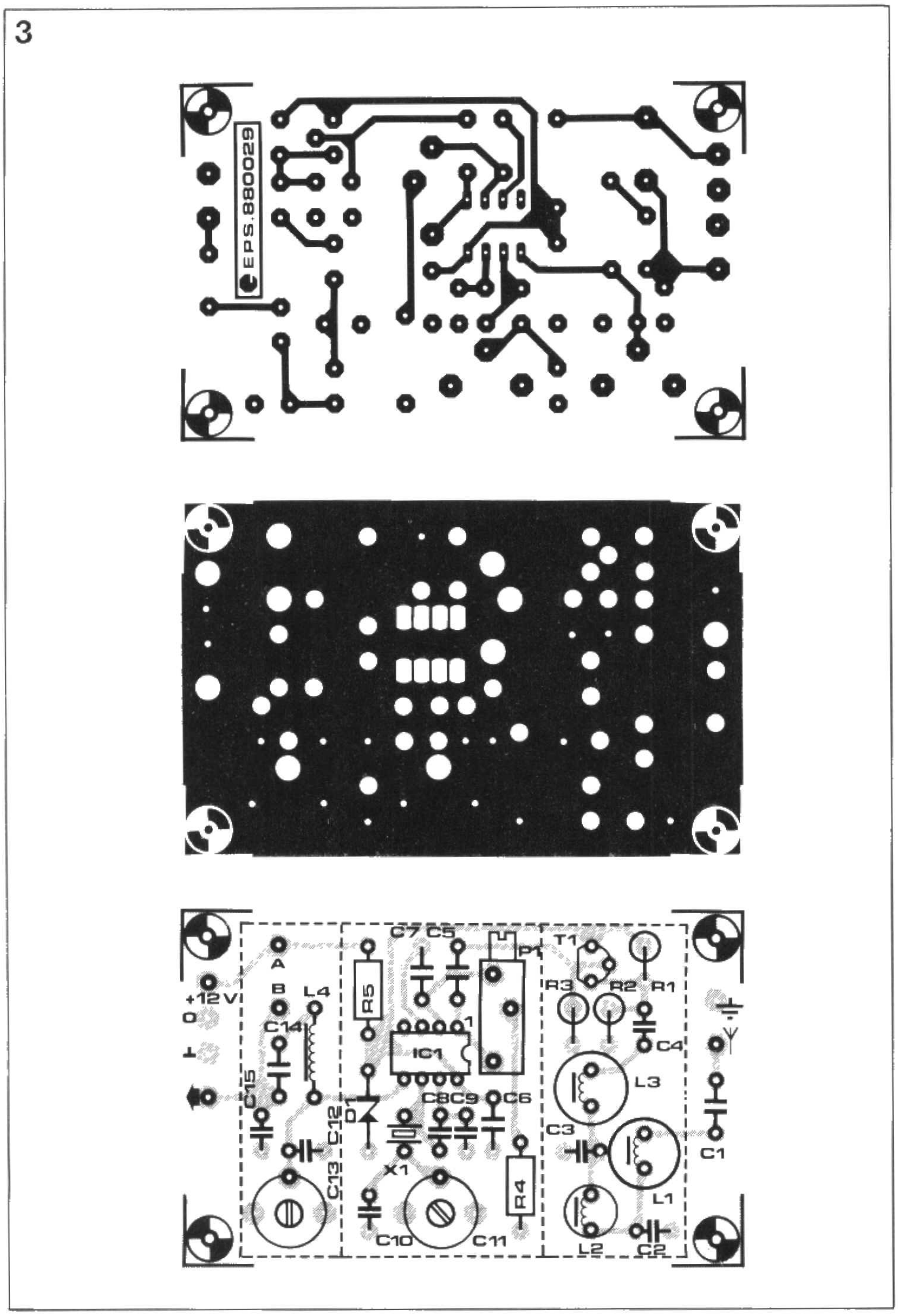



**Fig. 3. Printed circuit board for the VLF converter.**

**Parts list**

Resistors (±5%):

$R_1$;$R_2$ = 39K
$R_3$ = 3K9
$R_4$ = 10K
$R_5$ = 1K0
$P_1$ = 50K multiturn preset

Capacitors:

$C_1$ = 2n2
$C_2$;$C_3$ = 47p
$C_4$ = 3n3
$C_5$ = 33n
$C_6$;$C_7$ = 100n
$C_8$ = 100p
$C_9$ = 180p
$C_{10}$ = 18p
$C_{11}$ = 40p trimmer
$C_{12}$ = 68p
$C_{13}$ = 60p trimmer
$C_{14}$ = 1n0
$C_{15}$ = 330p

Inductors:

$L_1$;$L_3$ = 47mH ferrite encapsulated choke for radial mounting: Toko Type 181LY-473 (Cirkit stock no. 34-47302).
$L_2$ = 68mH ferrite encapsulated choke for radial mounting: Toko Type 181LY-683 (Cirkit stock no. 34-68302).
$L_4$ = 4μH7 axial choke.

Semiconductors:

$D_1$ = zenerdiode 6V8; 400 mW
$IC_1$ = NE602 (available from CSI Electronics)
$T_1$ = BF494 (Maplin order no. QQ19V)

Miscellaneous:

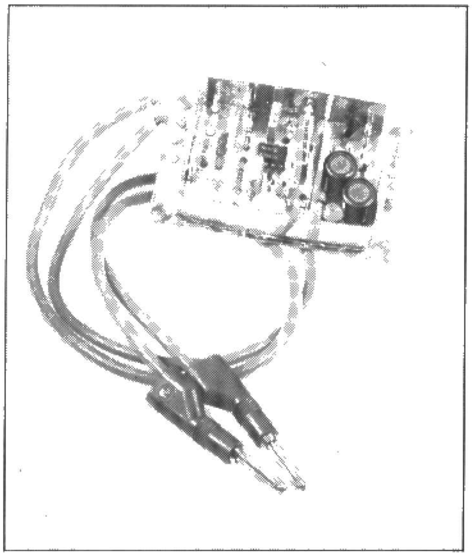
PCB Type 880029 (see Readers Services page).
$X_1$ = 10 MHz quartz crystal; 30p parallel resonant.

The output of the active double balanced mixer is a single-ended configuration. The up-converted frequency band is filtered in pi-section $C_{12}+C_{13}$-$L_4$-$C_{14}$-$C_{15}$ to suppress spurious mixer products. The low-frequency roll-off point of the filter is set to about 10 MHz by trimmer $C_{13}$. It should be noted that the mixer also generates an image band between 9.985 MHz (10−0.015) and 9.700 MHz (10−0.3), but this of little consequence. The converter is fed from a regulated 12 V source, either via separate supply wires (do not fit link A—B), or via the download coax to the receiver (fit link A—B, and make sure that the receiver output voltage is between 10 and 15 V). The mixer/oscillator and preamplifier transistor are fed from a 6.8 V rail created with stabilizer $R_5$-$D_1$.

## Construction and alignment

The VLF converter is a simple to build project. The printed circuit board is a double-sided, but not through-plated, pretinned type—see Fig. 3. Commence the construction with fitting 15 mm high brass or tin metal sheet screens as shown on the component overlay. Component leads shown without a small circle are soldered at the track side of the board, and to the ground area provided on the component side. Radial inductors $L_1$, $L_2$ and $L_3$ are ferrite encapsulated types from Toko. The mixer/oscillator, $IC_1$, is fitted direct onto the PCB (do not use a socket). Drill a 2 mm dia. hole in the screen to give access to the spindle of multiturn preset $P_1$. Finally, fit soldering terminals for the input, output and supply connections. Install wire link A—B if the converter is powered via the coax cable to the receiver.

Set $P_1$, $C_{11}$ and $C_{13}$ to the centre of their travel. Apply 12 V to the circuit, and check the presence of 6.8 V on pin 8 of $IC_1$. Measure the direct voltage on pins 1 and 2, and adjust $P_1$ until both are held at an equal potential of about 0.8 V. Connect the receiver, and tune this to 10.000 MHz. Mode: CW, BFO off, or to the centre of its travel. Switch on the input attenuator, or select reduced RF input gain. Lower the frequency of the beat note heard to nought by adjusting $C_{11}$ (zero beat). Connect the aerial to the VLF converter, and tune to a relatively strong transmission at



Completed prototype of the VLF converter. The screening fitted onto the component side prevents oscillation and spurious mixer products.

| Frequency | Station | Power | Service |
|---|---|---|---|
| 16 kHz | GBR Rugby (UK) | 60 kW | time signals during the 5 minutes preceding 03.00h, 09.00h, 15.00h and 21.00h. |
| 50 kHz | RTZ Irkutsk (USSR) | 50 kW | standard frequency. |
| 60 kHz | MSF Rugby (UK) | 50 kW | standard frequency & BCD time and date signals. |
| 71 kHz | *not identified* | | time signals. |
| 75 kHz | HBG Prangins (SUI) | 20 kW | BCD time and date signals. |
| 77.5 kHz | DCF77 Mainflingen (FRG) | 50 kW | standard frequency & BCD time and date signals. |
| 117.4 kHz | DCF37 Mainflingen | | meteorological facsimile. |
| 134.2 kHz | DCF54 Mainflingen | | meteorological facsimile. |
| 139.0 kHz | DCF39 Mainflingen | | photofacsimile. |

Some stations that can be received below 150 kHz.

about 200 kHz (10.200 MHz on the receiver), e.g. Droitwich (AM). Reduce the input gain of the receiver, and peak $C_{13}$ for optimum reception (this adjustment is relatively uncritical).

## Stations and services

It should be noted that the VLF converter has some conversion gain, so that every care should be taken not to overdrive the communications receiver. It is, therefore, strongly recommended to make use of the fixed or variable RF attenuator provided on most receivers. The connection between the VLF converter and the unbalanced, low-impedance (50—100 Ω) receiver input must be made in coaxial cable to prevent breakthrough of strong signals in the 10 MHz band.

The frequency assignment used in the VLF band is roughly as follows:

15—100 kHz: submarine communications (CW), beacons and time standard transmitters;
100—150 kHz: RTTY (radio teletype), and meteorological facsimile services;
150—300 kHz: long-wave broadcast services and, occasionally, RTTY.

# SIGNAL PROCESSING AND ELECTRONIC ENCRYPTION

by Brian P. McArdle

This article examines the effect of encryption operations on the usual understanding of signal processing.

Electronic signals are made secret by encryption operations. The original signals can be analogue or digital. For the purposes of this article analogue signals are complex waveforms made up of different frequencies. Digital signals are a sequence of pulses where each pulse can be identified as a particular bit (logic state 1 or 0) by reference to the voltage level, polarity, etc. They are also called mark and space pulses respectively. I do not intend to become involved in a detailed description of encryption, but to provide an over-view which should assist an electronics engineer or technician. For simplicity, the various encryption operations are considered to turn a signal into another signal of the same category, i.e., analogue signals after a scrambling operation are still analogue signals. Elaborate systems where analogue signals are sampled, turned into digital signals which are encrypted and transmitted in digital form are not considered. The paper explains two simple examples which can be altered as required. The comments and conclusions are of a general nature and may require amendment according to particular circumstances.

## Digital signal processing

Consider the encryption process illustrated in Figure 1. This represents a typical arrangement for the encryption and transmission of confidential information between message centres, such as

1

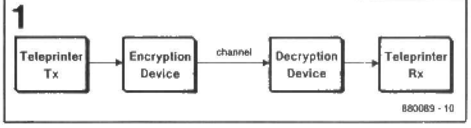



Fig. 1. Encryption of digital signals.

two embassies. If the teleprinter uses the CCITT Number 2 Code, each character pressed on the key-board will be represented as 5 bits plus start and stop bits. The electronic word is transmitted in bit serial mode (one bit at a time) to

the encryption unit. For simplicity, we will assume that the start and stop bits are not encrypted which is the procedure used in most cipher machines. The 5-bit block can be encrypted as a single block or one bit at a time. These are called Block and Stream Encryption respectively. (Usually blocks are made up of 64 or more bits.) The reader is referred to Ref (1) for an analysis of the various encryption operations. These need not be examined in this article. The actual electrical connection between teleprinter and encryption device is a 20 mA current loop illustrated in Figure 2. The start pulse has the same duration as a data pulse. The stop pulse is 1.5 times the duration. Hence, the code is referred to as a 7.5 bit code. There are 31 possible combinations ($2^5$-1) because the state 00000 is not used. The normal speed is 50 or 75 baud. There are other codes with other interfacing arrangements but the overall concept demonstrated by this example holds.

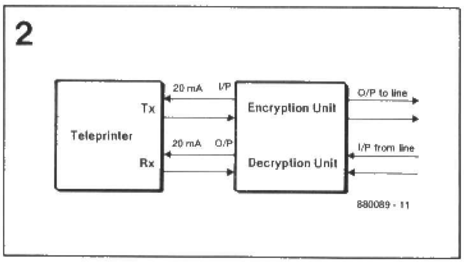



**Fig. 2. Interfacing arrangement using 20 mA current loop.**

The level of secrecy depends on the complexity of the encryption operation. This is usually varied by adjusting internal settings inside the device. Obviously, the same setting should not be used continuously. Otherwise the effect of the encryption operation would be cancelled or reduced considerably. An unauthorized listener (hacker) on the channel would probably know the arrangement but not the actual settings in use. There is always a very large number of possible settings in order to avoid deduction of a particular setting by trial and error. In cryptographic terms, the setting is generally called the key because it unlocks the information from confinement by a secrecy process. The reader is referred to Ref (2) for an analysis of the secrecy requirements of an encryption system. Basically it should not be possible to deduce the key by any method other than by trial and error. Hence the need for a very large set of possible keys. However, cryptosystems are not discussed in this article.

If the channel is a HF link, the output from the encryption unit becomes the audio input to the transmitter. This consists of 2 different tones with a frequency difference of 850 Hz between them. The upper frequency usually represents the "1" or mark pulse but this representation is sometimes reversed. This is known as Frequency Shift Keying (FSK)

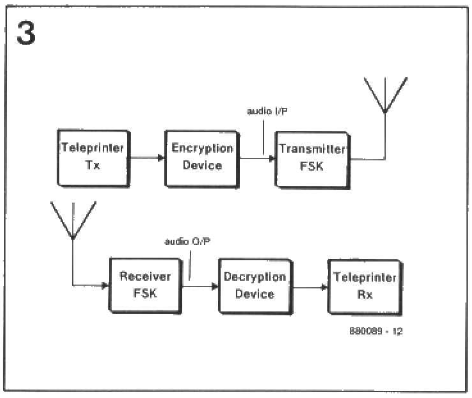



**Fig. 3. Communications over a HF radio link.**

and is explained in most modern text books on Telecommunications. It can be detected on most standard receivers by using Amplitude Modulation (AM) on Single Sideband (SSB). Obviously, the encryption unit must have the appropriate outputs to interface to the transmitter and not the smame arrangement as the interface to the teleprinter. The reverse procedure is applied at the receiver where the audio output is fed to the decryption unit. There are many other possible arrangements depending on the equipment and type of channel.

## Analogue signal processing

This is usually used to encrypt voice communications, such as over telephones and radio links. The encryption operation conceals the information contained in an analogue signal but the resulting encrypted signal is still in analogue form. A typical arrangement is shown in Figure 4. Usually, the

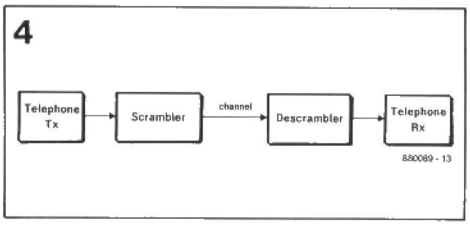



**Fig. 4. Encryption of analogue signals.**

scrambler unit cannot scramble and descramble simultaneously and consequently half-duplex operation must be used. The output from the scrambler is an analogue signal in the same frequency range as the original audio signal (refer to the assumptions in the opening paragraph of this article). A common method uses frequency inversion where parts of the analogue voice signal undergo an inverting operation which is controlled by a definite procedure inside the scrambler. The descrambler uses the same procedure and simply reverts the frequencies back to their original arrangement. The full operation is its own inverse which in turn facilitates implementation and use. However, analogue signal encryption is not considered to provide the same level of secrecy as digital signal encryption. This is because the cascaded substitution-permutation operations that provide real secrecy are more easily implemented with groups of bits. This statement requires further explanation in order to tie down the full problem.

Consider a digital system again as shown in Figure 5. The permutation operation re-arranges the order of the bits. For example, bit 9 moves to the 4th position and so on. The substitution operation divides the permuted block into sub-blocks of 4 bits each which is replaced by another block (e.g. 0100 becomes 1010).

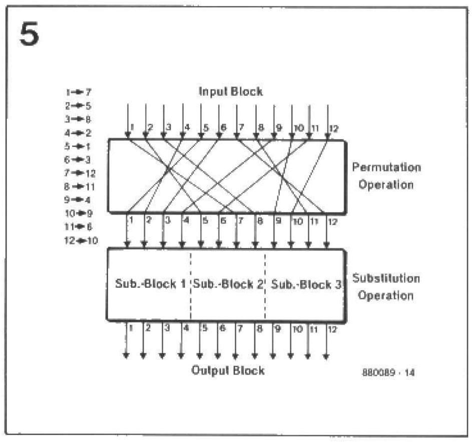



**Fig. 5. Permutation-substitution operation.**

Different replacement tables can be used for each sub-block. If these operations are repeated a number of times with different permutation and substitution tables, the entire process has a high level of secrecy. The complete operation is varied by changing the tables. The theory behind this procedure is explained in Ref (3) but need not be considered in this type of overview.

If the channel is a VHF radio link, the scrambled audio signal is used to modulate an RF carrier using the same methods of modulation as for unscrambled voice communications (AM and narrowband FM). There are other possible arrangements but they do not differ substantially from this example.

## Communications channels

The quality of a channel can have a major effect on encrypted signals. Consider the arrangement in Figure 1 again. If the channel is noisy, a pulse could be corrupted sufficiently for a "1" to be detected as a "0" or vice versa. This means that a bit in an electronic word is incorrect and consequently the decryption operation will produce a wrong character. If this type of corruption does not happen too often, the person who ultimately reads the decrypted message will notice the errors and be able to alter the text accordingly. However, a serious problem does occur where a decryption operation uses successive bits of a message in some inter-dependent fashion. This means that a sequence of words

would be reproduced incorrectly because of a single error. A simple arrangement is illustrated in Figure 6. The output bit from the encryption operation becomes part of the operation to encrypt the next input bit. Thus, successive output bits are linked together. A single error could have a disastrous result at the decryption stage. This example only uses one bit in the feedback loop but some systems could be using as many as 64 or 128 bits.

6

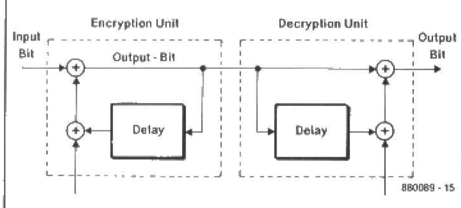



**Fig. 6. Inter-dependende between output bits (the + sign refers to addition modulo 2, which is an Exclusive OR logic operation).**

The reader is referred to Ref (4) on Cipherfeedback Mode which is a good example of this effect. If the channel is very noisy with a high level of corruption of the digital signals, a very reliable error detection/correction system must be installed between the encryption/decryption unit and the channel. The only alternative would be to transmit the information in plaintext without being encrypted which may not be satisfactory for the users.
Consider the example in Figure 4 again. Although it was not stated in the original explanation, a synchronization signal would probably have to be transmitted at regular intervals in order that the descrambler can reverse the scrambling process in the correct sequence. If the channel is noisy, a noise pulse could be interpreted as a synchronization signal by the descrambler such that the output signals turn into unrecognizable rubbish. This may not actually happen too often, but when it does communications are totally blocked. Alternatively, the scrambled signals may be corrupted but this may only affect certain frequencies. Voice communication has a very high level of redundancy and even noisy messages can sometimes be understood by an experienced operator. However, in general analogue signal encryption requires a good channel for reliability. Otherwise it may simply not work.

## Conclusions

There is an obvious problem with analogue signals. Remember that these are essentially little packets of different frequencies that together form the signals, which in turn become the information. The various operations of encryption, transmission over a channel and decryption must reproduce the original signals as accurately as possible. In reality, these are difficult requirements to satisfy. For example, to compensate for a noisy channel, the encryption operation may have to be simple and straight-forward, which in turn reduces the level of secrecy. This could mean that the effect of encryption is to provide privacy rather than secrecy (in this context, privacy means secrecy against members of the general public rather than code breaking organizations, such as the National Security Agency in the U.S.). However, encryption operations that require bits, such as the Data Encryption Standard, are much more flexible. They only require a single bit or block of bits as the input. The key or control to vary the operation is generally also a block of bits. The full operation can be described with Boolean Logic Operation(s) which are now known by 1st year students. Thus the whole area of encryption and secrecy seems to favour the use of digital rather than analogue signals.

**(6) References**

1. Denning, Doroty E.; *Cryptography and Data Security.* Addison-Wesley: U.S.A. (1982).
2. Hellman, Martin E. and Diffie, Whitfield; ''Privacy and Authentication: An Introduction To Cryptography''. *Proceedings of the IEEE*, volume 67, number 3 (1979).
3. Shannon, Claude E.; *Mathematical Theory of Communications*. University of Illinois Press: U.S.A. (1962).
4. ''Data Encryption Standard''. *FIPS PUB 46*, National Bureau of Standards, Washington D.C., U.S.A. (1977).

# RADIO & TV NEWS

## BBC leads Europe

The BBC is leading the way in Europe with a new system that will allow the ''intelligent'' receiver to automatically tune to the best signal, give a visual indication of the station name, and display the time and date.
BBC engineers have recently completed the installation of Radio Data System (RDS) equipment at all of its Network and Local Radio VHF FM transmitters. The RDS data, which is currently statically configured, is carried on an inaudible 57 kHz sub-carrier on every VHF FM transmitter. The codes being transmitted conform to the European Broadcasting Union (EBU) specification, and consist of PI (Programme Information), PS (Programme Service), AF (Alternate Freuqneyc), ON (Other Network Information), and CT (Clock Time dand Date).
The RDS service will be publicly launched at the BBC Radio Show to be held at Earl's Court, London, from 30 September to 10 October this year. It is expected that many of the manufacturers currently developing RDS receivers will have them available for sale by then.

## Astra launch date rescheduled

SES (Société Européenne des Satellites) has been informed by Arianespace that Astra's launch date has been rescheduled from September to October this year.
At the same time, it has been announced that the SES/British Telecom Joint Venture board have finalized details on the agreement to market ASTRA transponders to UK programmers. As reported early last year in this magazine, British Telecom are leasing 11 of the 16 transponders from SES.

## Dish for Europe

Satellite Technology Systems have completed their design of a dish antenna for the reception of ASTRA satellite TV broadcasts. Initial production capacity will be 500,000 units per annum, which will ensure volume supply to European distributors.
The dish material is aluminium for stiffness, strength, low weight, and durability. Unlike plastics, aluminium is not affected by extremes of temperature or ultra-violet light.
The dish is aimed primarily at OEM customers. These may be electronics manufacturers wishing to offer a complete system, distributors, wholesalers, retail chains, or satellite operators.
Further information from Satellite Technology Systems Ltd • Satellite House • Blackswarth Road • BRISTOL BS5 8AU • Telephone (0272) 554535.

## Mobile Radio Conference

The Mobile Radio Community is an expanding industry with tremendous growth potential and plenty of job opportunities for highly trained technicians and engineers, but as yet this industry can not find the qualified manpower to fill the many openings within the industry.
Rather than continuously bemoaning this fact, the MRUA — representing the mobile radio community since 1953 — in close co-operation with the DTI have

decided to take action and initiate the MOBILE RADIO — EDUCATION — NOW! Conference at Regent's College, Regent's Park, London on 4 and 5 May. The conference will bring together representatives from the mobile radio industry, DTI, users, technical colleges, interested trade union educational bodies, students, and so on, to discuss the needs and how they can best be met in the short and long term.
Further information from: Mobile Radio User Services Ltd • 28 Nottingham Place • LONDON W1M 3FD.

## Anglo-French "Screensport"

W.H. Smith has joined forces with Compagnie Générale des Eaux to launch a French-language version of "Screensport", the satellite sports channel.
"Screensport", W.H. Smith's sports channel, has been in existance since 1984 and has a subscriber base of about 400,000 in Great Britain and Scandinavia. "TV Sport", as the French channel is called, will use the same visual images as "Screensport", but will have a French soundtrack.
Transmission of "TV Sport" is via the same transponder as "Screensport" (Intelsat V at 27.5° W) and is beamed at viewers in France, Belgium, Switzerland, and Luxembourg.

## Video signal identification

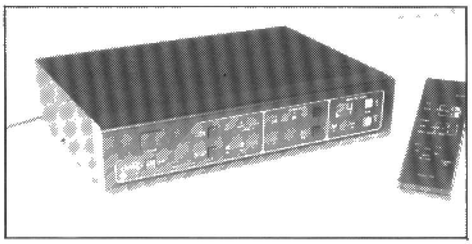
Seltech have developed a system that allows TV broadcasters to instantly identify the sources of incoming video signals. The Remote Source Identification System (RoSIE) is designed to label incoming electronic news gathering (ENG) and outside broadcasting (OB) video sources.
The system is said to be particularly effective when signals are being received from a large number of sources, and can also be used to pass general information to the base station as well as perform the identifying label function.
Further information from: Seltech International Ltd • Rose Industrial Estate • Cores End Road • BOURNE END SL9 5AT • Telephone (06285) 29131.

## Timecode system for videotape

A timecode system — the equivalent of frame numbering on film — that can be used on all videotapes without losing an audio track has been developed by IMP Electronics.
The "Vidchron" vertical interval timecode system can be used on Lo-Band and VHS tapes on which VITC is usually unreliable because of their narrow bandwidth. The Vidchron timecode can be read regardless of the playback speed and can be recovered reliably up to 5th generation recording on VHS.
No special operations or machine modifications are required during copying or playing and any video cassette recorder can be used.
Further information from: IMP Electronics • Stanton House • Station Raod • Longstanton • CAMBRIDGE CB4 5DS • Telephone (0954) 60595.

## Store up to 60 satellite locations

The Micro Eye ADU 2010 may be interfaced with BEL's Micro Eye SBR 2050 satellite receiver for automatic satellite selection. The unit is operated through the front panel keyboard or by remote control. The antenna drive unit is equipped with a satellite memory. What-



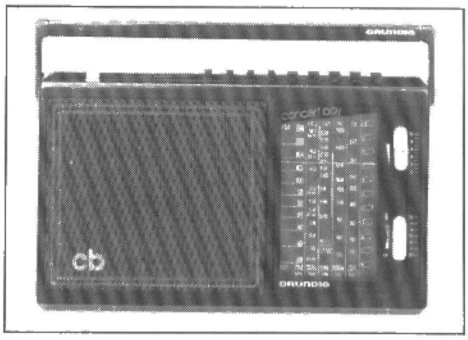
ever your channel or satellite selection, the memory control will return precisely to any pre-determined satellite position: quickly and easily. The possibility of under- or over-shooting is eliminated.
Further information from: BEL-Tronics (UK) Ltd • Cherry Orchard North • Kembrey Park • SWINDON SN2 6BL • Telephone (0793) 619100.

## INMARSAT contract for DCC

INMARSAT has awarded a $5.2 million contract for equipment and software that will enable it to introduce satellite communications to small mobile terminals world-wide from the middle of next year. The contract has been placed with DCC Ltd of Milton Keynes, and is for three sets or Networks Co-ordination Sation (NCS) equipment for INMARSAT's Standard-C system.
Under the contract, DCC will act as prime contractor and supply the NCS software, while specially developed Standard-C modulators and demodulators will come from Hughes Network Services, Inc. of Germantown, MD, USA.
Further information from INMARSAT • 40 Melton Street • LONDON NW1 2EQ • Telephone 01-387 9089.

## New radio from Grundig

Grundig have added the new Concert Boy to their range of portable radios. This compact radio covers the MW, LW, FM (with AFC and four presets), and



two SW bands (5.8-6.4 MHz and 6.8-18.5 MHz). Other features include slider volume and tone controls; large wide-band loudspeaker; 1.5 W music power output; 3.5 mm headphone socket and mains or battery operation. It is available in black and the price is £39.95.
Grundig International Ltd • Mill Road • RUGBY CV21 1PR • Telephone (0788) 77155.

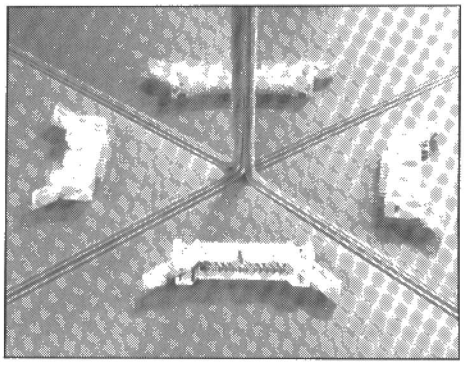
## Greek order for Eddystone

Eddystone Radio, the Birmingham-based division of Marconi Communication Systems, has won an order to supply the first commercial radio station in Greece with VHF FM transmitting equipment. The station, to be known as "Top FM", will be located on Mount Parnis to the northwest of Athens at a height of 1,200 metres. It will serve listeners in the Athens/Piraeus basin, an area with a population of some 2.5 million people.
Marconi Communication Systems • Marconi House • New Street • CHELMSFORD CM1 1PL • Telephone (0245) 353221.

## Programmable delay line

A programmable delay line IC, which uses charge-coupled devices (CCD), overcomes the problems associated with passive delay line that use ultrasonic transmission in glass or LC(R) networks.
Designated WA1101, the IC offers standard delays of 350, 700, 1,000, and 1,400 ns for video signals (though other periods can be obtained by adjusting the device's internal clock).
Since there is no liability to inaccuracies caused by ageing or temperature drift, the WA1101 is ideally suited to applications in high-quality TV and video equipment, radar, and sonar.
Further information from: Walmsley Microsystems Ltd • Aston Science Park • Love Lane • BIRMINGHAM B7 4BJ • Telephone 021-359 0981.

# COMPONENT NEWS



## Low profile headers compatible with BT224

Five Star Connectors has introduced the BT224-compatible Spectrastrip four-wall range of headers. The four wall construction ensures correct polarisation and provides contact protection.

Offered in straight or right-angled versions with either short or long latches in 10 - 50 ways, these headers are moulded in glass-reinforced thermoplastic with an operational temperature range of −55°C to +105°C. Phosphor bronze contacts are plated with gold over nickel and feature a contact pitch of 0.10in.

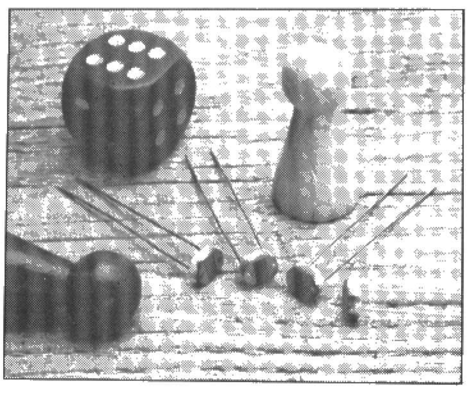
**Five Star Connectors • Edinburgh Way • HARLOW CM20 2DF. Telephone: (0279) 442851.**

## New photoconductive cells

Quantelec has introduced two new ranges of photoconductive cells. Supplied by Sentel GmbH in West Germany, the PCPY and PCKY ranges of cells are designed for use in conjunction with Sentel's range of infrared pyro detectors in security and lighting applications.

The PCKY cells offer a light resistance of 10 to 30 kΩ at 10 Lux with a light source of 2850 K. Dark resistance after 10 seconds is 0.5 MΩ minimum at an applied voltage of 5 V. Power dissipation is 30 mW continuous whilst maximum voltage is 100 V. Maximum spectral response of the PCKY is 5500 ±300 Å and ambient temperature range is −30 to +70°C.

The PCPY cells feature a light resistance of 20 to 100 kΩ at 10 Lux and 5 kΩ (typical) at 100 Lux with a light source of



2850 K. Dark resistance after 10 seconds is 20 MΩ minimum. Power dissipation is 60 mW continuous, 90 mW demand both at 25°C. Maximum voltage is 200 V. For the PCPY cells, maximum spectral response is 5500 ±300 Å and operating temperature range is −30 to +60°C.

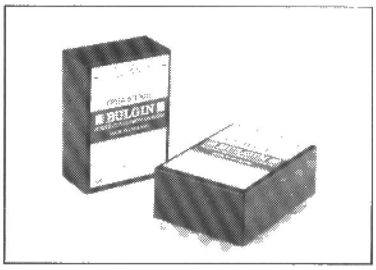
**Quantelec Limited • 46 Market Square • WITNEY OX8 6AL. Telephone: (0993) 76488.**

## Cost effective encapsulated linear power

Now available from Cirkit Distribution are Bulgin 5 watt encapsulated EP linear power supplies, designed for mounting directly onto printed circuit boards.

Measuring 89 × 63 × 32mm they feature industry standard foot print pinouts.

The power supplies are housed in ABS boxes which are encapsulated with flame retardant polyurethane and fitted with two M3 bushes for mechanical support. Available with two input ranges (210 to 250 VAC and 100 to 120 VAC), the products cover most popular voltages in single, dual and triple format. Custom requirements can easily be catered for with 1-3 outputs and 6 watt maximum load.




The design provides 3.75KV RMS input to output isolation with all outputs being short circuit protected.

**Cirkit Holdings PLC • Park Lane • BROXBOURNE EN10 7NQ. Telephone: (0992) 444111. Fax: (0992) 464457. Telex: 22478.**

## K-ROGET Thesaurus for PC Compatible Microcomputers

Kuma Computers have announced K-ROGET, the disc-based thesaurus based on the internationally acclaimed *Longman Pocket Roget's Thesaurus*, operating under PC-DOS.

K-ROGET includes over 150,000 words and phrases, providing an essential aid to writers and speech makers. K-ROGET helps to express thoughts more clearly and effectively by providing the user with a selection of words with similar meanings, this helps to add a great deal of polish to essays, manuals and other documents.

K-ROGET operates as a Hot Key background program, making it accessible from most PC word processing packages. It is both intuitive and easy to use: the word to be replaced is selected from the document and 'sent' to K-Roget, when an alternative word is chosen, it can be 'sent' back to the word processor document in the same way without the need for retyping.

K-Roget also has a Phonetic Spelling Checker and a 'Past' facility. 'Past' keeps track of the words selected in a search, enabling the user to retrace through previous selections to choose the most suitable word. The Phonetic Spelling Checker traps words mis-spelt as they sound (the most common source of mis-spelling) and offers possible alternatives, an essential feature for anyone who has ever tried to check an incorrectly spelt word in a printed thesaurus!

K-ROGET under PC DOS is available now at a retail price of £49.95 including VAT, a version operating under GEM is also available.

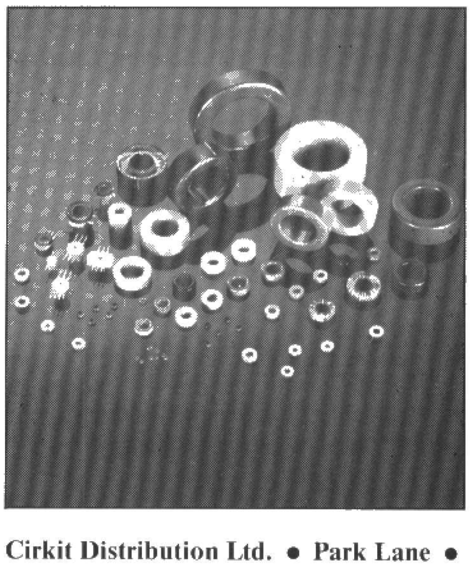
**Kuma Computers Ltd • 12 Horseshoe Park • PANGBOURNE RG8 7JW. Telephone: (07357) 4335.**

## RF iron powder cores

An extensive range of iron powder toroidal cores and mounts for RF applications is now available from Cirkit Distribution Ltd.

Iron powder has been widely used as a core material in RF circuits for many years, and is preferred due to its stability, frequency response, high 'Q' and narrow permeability tolerance. Close uniformity within lots and relative unformity from lot to lot are additional features. Inductance tolerances are ± 5%.

A book offering product selection is available from Cirkit and includes useful design information for the engineer.



**Cirkit Distribution Ltd. • Park Lane • Broxbourne • EN10 7NQ. Telephone: (0992) 444111. Fax: (0992) 464457. Telex: 22478.**